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World Year of PHYSICS 2005

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2005

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W: Electroresponsive Polymers and Their Applications

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OO: Growth, Modification, and Analysis by Ion Beams at the Nanoscale

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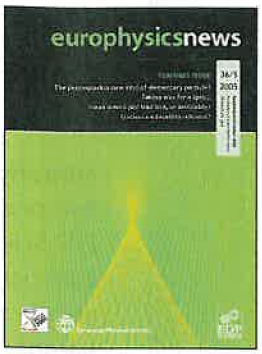

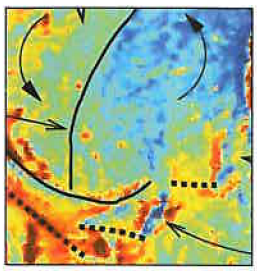

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NEWS, VIEWS AND ACTIVITIES

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europhysicsnews

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The Physics that was Unlocked by Albert Einstein

Martin C.E. Huber,
Vice-President of the EPS.

Beyond Einstein – Physics for the 21st Century, the 13th General Conference of the EPS was the scientific finale of the centenary celebrations of the annus mirabilis in Bern.

At preparatory meetings for the 'World Year of Physics' people often commented that the Einstein Centenary Celebrations in Bern might become one of the high points, if not *the* high point of WYP2005. And, indeed, they were! 'Forum Einstein 2005 Bern', an association of institutions of education and science, had made plans for a sequence of public events taking place in the months leading up to July 2005. These comprised a discussion forum on "The Culture of Innovation from Science to Product", a one-day seminar about Einstein's relationship to music, and talks and debates by historians of science on Einstein's discoveries[1]. Upon an International Celebration Day, on Saturday 9 July, consisting of a Symposium on "Perspectives for Physics in Einstein's Tradition"[2] and an Official Ceremony under the auspices of Mr. Samuel Schmid, President of the Swiss Confederation, followed the 13th General Conference of EPS, EPS13, which dovetailed into the Annual Congress of the Swiss Academy of Science and an Open Day organised jointly by the Academy, EPS, the Swiss Physical Society and others.

The official celebration of 9 July 2005 took place in the late afternoon, following a morning of talks to an overflow audience by Anton Zeilinger (A), the Nobel Laureate Claude Cohen-Tannoudji (F) and Alan Guth (USA). The President of the Swiss Confederation, Samuel Schmid, opened the Celebration in the concert hall of the Bern 'Kulturcasino', where well over a thousand guests from politics, science and industry as well as from the public at large had gathered. President Schmid considered that the prime reasons for Einstein's becoming an idol were his civil courage and humanity. The scientist Einstein was convinced that care of human beings must be the main aim of all technical efforts. Einstein, as a human being, also lived 'the liberty of being allowed to be different, and had the will to think beyond the point, where others stopped.' This liberty, Schmid said, may have been underlying current of the development of Einstein's outstanding abilities.

The Director General of UNESCO – the organisation that had declared the 'World Year of Physics 2005' – spoke next, and expressed his hope that the World Year would bring more young people to physics and, in general, would result in a better understanding of the qualities of this central scientific discipline.

Anders Bárány, of the Nobel Museum, then gave an account of the developments that had led to Einstein's Nobel Prize. Apparently, Einstein's main relief after the award was that he didn't have to hear the enquiry "Why don't you receive the Nobel Prize?" Einstein, it is now agreed, did contribute more to the prestige of the Prize than *vice-versa*.

Iris Zschokke-Gränacher, a Swiss physicist who had helped guide Swiss science policy in many honorary functions, mentioned numerous applications that had come out of Swiss institutions performing basic research in physics and are taken for granted today. She drew urgent attention to the need for proper funding of basic research. She also stated that the potential European Research Council, must add to, not replace, national science funding.

The 'father of Quarks', Nobel Laureate Murray Gell-Mann, then received the 'Bern Einstein Medal' in recognition of his achievements in a life of science. In his speech, he illustrated creative thinking that jumps over borderlines – and also sometimes can go wrong in real life ('why not' in the case of Enron, for example!) – to a highly appreciative audience.

Brief musical interludes, among them a performance of 'Five Madrigal Stanzas' for violin and piano that by Bohuslav MartinÛ had composed for the violinist Albert Einstein, were nicely interspersed between the various speeches.

As stated at the outset, the EPS13 Conference was the scientific finale of the celebrations. It was devoted to the professional physicist, and started on Monday morning, 11 July 2005 with three welcome addresses by the Rector of the University of Bern, Christoph Schäublin, the Swiss Secretary of State for Education and Science, Charles Kleiber, and the EPS President. The latter reminded the audience that physics and closely related sciences in Europe are blossoming, as evidenced by many major physics facilities being constructed in Europe, such as the LHC and ITER and fine facilities run by ESA and ESO – in space and in Chile. Nevertheless, there was still a net brain drain out of central and eastern, but also western Europe. Thus, better career prospects for physicists must be provided in Europe, and EPS will have to continue working on assuring that physics as a profession fares better in Europe.

Three magnificent plenary talks on '100 Years of Relativity', 'Attosecond Lasers', and 'Brownian Motion and Later Develop-

▲ Fig. 1: In the 'Green Room' before the official celebration: the President of the Swiss Confederation, Samuel Schmid, speaking with the Director General of UNESCO, Prof. Koïchiro Matsuura. In the background the Vice-Director of the Nobel Museum, Stockholm, Anders Bárány, who later spoke about the prolonged developments in the Nobel Physics Committee that led to the award of the Nobel Prize to Albert Einstein. (Photo: Eidg. Dept. f. Verteidigung, Bevölkerungsschutz und Sport, VBS)

[1] The talks and debates by historians of science on Einstein's discoveries have been recorded on DVD

[2] The talks by A. Zeilinger, C. Cohen-Tannoudji and A. Guth at the International Symposium on "Perspectives for Physics in Einstein's Tradition" have been recorded on DVD.

▲ Fig. 2: The main organiser of the WYP2005 event 'Physics Enlightens the World' and the EPS President frame national organisers who made particularly successful efforts in realising the event.

ments' then opened scientific part of EPS13. The speakers, respectively, Thibault Damour, Ferenc Krausz and Giorgio Parisi thus introduced the audience to the current status of the blossoming fields that had been unlocked by Einstein in 1905. Thibault Damour, who at the same time received the Cecil F. Powell Memorial Medal in recognition of his efforts towards achieving a grand unification of all fundamental forces, discussed the role of the theories of Special and General Relativity in the present framework of physics, summarised their experimental verification, and presented the motivation for further tests. Ferenc Krausz reported on the progress towards the development of laser pulses with a duration between 10^{-14} s and 10^{-18} s, i.e., an attosecond. The reproducible generation and measurement of isolated 250-attosecond extreme ultraviolet pulses and first attosecond time-resolved observations of atomic electron dynamics demonstrate that tools and techniques for studying the motion of electrons in the microcosm, i.e., at atomic and molecular length scales, are now becoming available. Giorgio Parisi demonstrated the enormous influence and potential of Einstein's paper on the Brownian motion. He explained that the paper was one of the first successful applications of statistical mechanics beyond kinetic theory of gas, and that it was extremely important in convincing scientist at the time of the existence of atoms.

During the main part of EPS13, namely the three parallel conferences with the themes: 1. "Photons, Lasers and Quantum Statistics", 2. "Relativity, Matter and Cosmology" and 3. "Brownian Motion, Complex Systems and Physics in Biology", which took place from Monday afternoon until Thursday afternoon – participants discussed in depth the state of the art of the fields that Albert Einstein had unlocked in Bern early in the 20th Century. All EPS Divisions were involved in the organisation, several of them collaborating in the three parallel conferences. Moreover, ESA, ESO and CERN had decided to hold their triennial joint Symposium together with the second Conference on 'Relativity, Matter and Cosmology'.

The interest in EPS13 among the community was therefore large: 570 physicists had registered. A fund of 65,000 € had been accumulated over the three years since EPS12, and this permitted EPS to award grants to numerous scientists. Many of these scientists were at the beginning of their career and from countries, where national funding might have permitted attendance for very few, if any! Also, thanks to the support of the Regional UNESCO Regional Office for Science in Venice, EPS-UNESCO (ROSTE), short-term fellowships could be given to a number of young scientists from South-Eastern European countries.

The EPS13 participants had several opportunities for respite from the rigours of science. A reception at the Historical Museum, where the Major Special Exhibition 'Albert Einstein (1879-1955)' could be visited, took place on Monday evening. And 'Symmetry, Music, and the Flow of Time – some thoughts about art, symmetry and science, put into words and music on two grand pianos' was the title of a cultural presentation at the 'Hochschule der Künste' scheduled on Tuesday evening. There was, of course, also a Conference Dinner, offered at two places, namely in the traditional 'Kornhauskeller' and in the recently opened 'Paul Klee Zentrum' that has been designed by the architect Renzo Piano.

Another high point, again of scientific nature, was the award of the *Europhysics-Agilent-Prize*, to David Awschalom (USA), Tomasz Dietl (Poland) and Hideo Ohno (Japan). The laureates, who have pioneered, in international collaboration, the promising area of 'spintronics' with their work on spin effects in semiconductor materials, each gave an *aperçu* of their contributions to the achievement being honoured. And, of course, there was the General Meeting, where the President, the Executive Secretary and the Secretary General reported on the state of the Society. In a further award ceremony, John Lewis received the Thomas Medal in presence of Edit Thomas, Martial Ducloy was awarded the Prize for 'Public Understanding of Physics', and further honours were bestowed on physicists who had been particularly active in their national light relays of WYP2005 – 'Physics Enlightens the World'.

On Friday, 15 July 2005, the last day of EPS13, EPS joined with CERN, EFDA/JET, ESA, ESO, the Swiss Academy of Sciences, the Swiss Physical Society and the Institute of Physics in Bern, in offering a day of the open door to the public at large. Over a thousand people took advantage of this opportunity, which – among many other attractions – featured demonstrations of the Danish Group 'Fun Physics' and also, in the afternoon, a webcast, where sites of CERN in Geneva, ESO in Chile, ESA in Noordwijk and EFDA/JET in Culham, U.K., were visited with a two-way video link, and where the audience could ask questions (in some cases even in the local Bernese dialect) about the scientific work and also the daily life of the researchers in their international environment.

The overall event of the Einstein celebrations of the 'Forum Einstein 2005 Bern' concluded with a loud, but relaxing one-hour jazz concert in the tent set up in front of the Building for Exact Sciences. Here the EPS Presidency was handed over to Ove Poulsen, and as a permanent mark of the Einstein celebrations, the 'Einsteinterrasse' was inaugurated.

After all these celebrations have become history, a visit to the city, which was Einstein's home early in the 20th Century is still worthwhile: not only the 'Einsteinterrasse', also the 'Einsteinhaus' – renovated and extended in view of the centennial of the *annus mirabilis* – and an 'Einstein Path' guiding the visitor on the vestiges of Albert's daily life, remain and are accessible to visitors. Moreover the superb exhibition "Albert Einstein (1879–1955)" in the Historical Museum Bern will remain open until 17 April 2006.

Thanks are due to many people who have helped making EPS13 a success: Martial Ducloy, the Chair of the International Programme Committee; the Conference Co-ordinator, Christophe Rossel; the Chair of the Local Organising Committee, Hans Balsiger; the Corresponding Chairs of the three parallel Conferences, namely Sandro de Silvestri, A.M. Cruise and Jean Pierre Boon; Ophélia Fornari from the EPS Conference Services, and all their helpers, all the speakers, poster presenters and general participants. ■

More pictures to be seen in a coming issue of Europhysics News

The pentaquark: a new kind of elementary particle?

Klaus Goeke [1], Hyun-Chul Kim [2], Michał Praszałowicz [3]
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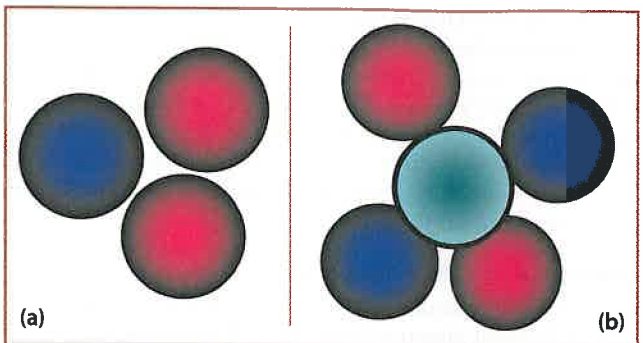
Despite intensive experimental studies for half a century and theoretical work based on Quantum Chromodynamics (QCD) in the last 30 years, our understanding of nucleon structure is still far from being complete. This is reflected by the several competing models of nucleons or, more broadly, light baryons, as e.g. various constituent quark models with gluonic or chiral forces, or topological and non-topological solitonic models. There are also sum-rule approaches and lattice gauge calculations, which are less model dependent but not always reliable. This situation is unsatisfactory. Nucleons are the main building blocks of matter around us, they provide the mass for the baryonic (i.e. visible) matter of the universe, and we need to understand their structure and their dynamics.

In this situation the prediction and discovery of the narrow baryonic resonance Θ^+ with strangeness of +1, i.e. containing one excess strange anti-quark, may prove to be extremely important, since it perhaps indicates the existence of a new class of baryons, and this may shed a completely new light on the present models for baryon structure. Actually the Θ^+ has a mass of 1530 MeV, compared e.g. to 938 MeV for the nucleon, and a decay width of the order of 1 MeV, which is two orders of magnitude smaller than expected for baryons in this energy region. It has in 2002 and 2003 been identified by several groups [1] using different reaction processes. Such a state is extremely exciting because it is unambiguously exotic in the sense that it cannot be a simple three-quark state. These experiments have been triggered by predictions of mass and decay width in the chiral quark soliton model (χQSM) by Diakonov, Petrov and Polyakov [2] in St.Petersburg and Bochum. An earlier estimate of the mass in the soliton approach of the Skyrme model was given by Praszałowicz [3] in Krakow. The discovery of Θ^+ together with the accurate prediction of Ref.[2] have initiated considerable theoretical activity. The discussion got even very heated since several other experiments in the last year, mostly of higher energy, did not show any evidence of the Θ^+, see refs. [4]. Besides the Θ^+ there is perhaps an observation of an exotic $\Xi_{\overline{10}}$ state at 1860 MeV by the NA49 experiment at CERN [5], though it is still under debate. Much of the theoretical activity has been aimed at understanding the structure of these exotic states, Θ^+ in particular. Besides using the chiral solitonic approach the most common treatment of this problem has been based on extensions and variants of the constituent quark model [7] and of the Skyrme model [8]. While these approaches are all interesting, they all are also highly model-dependent and it is difficult to assess in an *a priori* way their validity.



▲ **Fig. 1:** (a)The structure of the proton with two up- and one down-quark (*uud*). (b)The structure of the Θ^+ with two up-quarks, two down-quarks and one strange anti-quark ($uudd\bar{s}$).

The analysis based on the SU(3) chiral soliton model [2] appears different from other treatments of the Θ^+ structure in a number of ways: I) Exotic SU(3) representations containing exotic baryonic states are naturally accommodated within the chiral soliton models [3]. II) The soliton approach was used to *predict* exotic states by linking their properties to the known baryons in octet and decuplet of $SU(3)_{flavour}$. In contrast to the other treatments it preceded experimental discovery by many years. III) Despite some freedom as far as model parameters are concerned the predictions of the mass were very accurate [2, 3]. IV) The width was predicted to be very small [2], which is consistent with the widths presently observed [9].

In the present paper we will in the first part review the quark model of baryons and give some historical background. Then we discuss the deficiencies of the quark model, consider spontaneously broken chiral symmetry, and focus our attention on the solitonic (mean field) approach to the Θ^+ and the anti-decuplet in the framework of a relativistic quantum field theory [6]. A discussion of the decay width and a report on the discovery of Θ^+ finalizes the paper.

The quark model: history and presence

In 1963 Gell-Mann and Zweig suggested a model for the nucleon and the light baryons which was based on the concept of group theory. They were able to classify the baryons by the quantum numbers of isospin T, T_3 and hypercharge Y, characteristic of the multiplets of the symmetry group SU(3)-flavour. The model was formulated in terms of quarks, that constituted the fundamental representation of SU(3). The model turned out to be highly successful and allowed Gell-Mann to predict the existence of a new particle, the Ω^-, which was rather soon identified experimentally. The model was then extended dynamically involving phenomenological potentials, in which the quarks moved, or appropriate quark-quark interactions, which in the modern terminology consisted of confining potentials and gluon and/or meson exchange forces. The forces and quark masses were adjusted to observables of the baryons as masses, magnetic moments, radii, etc. In the end the following picture emerged: The nucleon and the light baryons consist of three quarks with spin = 1/2 and with flavours up, down and strange. These have fractional charges $Q = 2e/3$, $-e/3$, $-e/3$ and masses of about 350 MeV for up- and down-quarks and for the strange quark about 100-200 MeV heavier. For example the proton consists in this scheme of two up-quarks and one down-quark (*uud*, see fig.1a). The baryons can be arranged in octets and decuplets of the *SU*(3) flavour group, characterized by quantum numbers of isospin T, T_3 and hypercharge Y and combined with an antisymmetric colour structure. All attempts to

find structures not belonging to this scheme, e.g. containing another number of quarks or besides quarks also a few anti-quarks, were in vain. This historical circumstance led to the wide-spread belief that 'exotic' baryons, which cannot be constructed of three quarks and belong to higher $SU(3)$ multiplets, do not exist. This belief might be now discredited with the discovery of the Θ^+. It has the quark structure $uudd\bar{s}$ and hence consists of five (Greek: penta) quarks rather than three, see fig.1b.

Concept of constituant quarks

In the 1970's Quantum Chromodynamics (QCD) was formulated as a relativistic quantum field theory of the strong interaction involving quarks as particles and gluons as interacting field quanta. As far as the up-, down- and strange sector was concerned, these quarks have small masses of $m_u \simeq 4$ MeV, $m_d \simeq 7$ MeV (and $m_s \simeq 150$ MeV) and are so called current quarks to be distinguished from constituent quarks in the quark models of about 350 MeV. For massless quarks (and even 150 MeV is nearly massless) the QCD-Lagrangian shows chiral symmetry. This means that in the QCD-Lagrangian right-handed quarks do not interact with left-handed ones and vice versa. However this symmetry is not realized in nature but is spontaneously broken. This effect occurs analogously in ferromagnetism, where the forces which couple the electronic spins and hence the Hamiltonian of the system are rotationally invariant, whereas in the ground state the spins are aligned in some definite direction resulting in a non-zero magnetization and violation of the rotational symmetry.

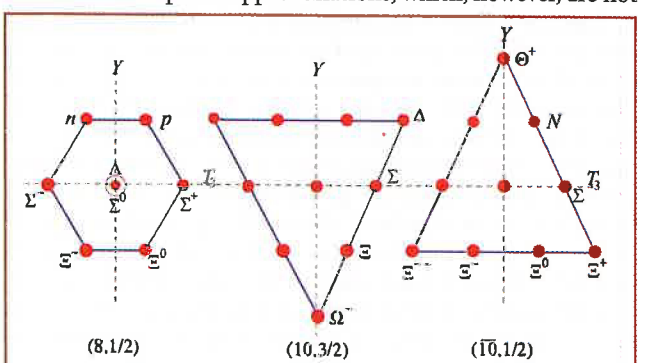
For the structure of light hadrons this spontaneous breaking of chiral symmetry is probably the most important mechanism. This effect has its origin in the zero-point quantum fluctuations of the gluon field in the vacuum of QCD. Peculiar for QCD is that there are specific large fluctuations called instantons with average size and average separation of roughly 1/3 fm and 1fm, respectively. If light quarks propagate through this fluctuating gluon vacuum, "hopping" from one randomly situated instanton fluctuation to another, they behave like electrons in a lattice structure, i.e. they gain an effective mass which in the case of the quarks is a large dynamical momentum dependent mass $M(p)$ serving of equal importance as the quark-pion coupling constant. This dynamical mass is the key for understanding the properties of light hadrons. Its value at zero momentum, $M(0) \simeq 350$MeV, is what is usually called the "constituent" quark mass (to be distinguished from the small input "current" quark masses of the QCD Lagrangian). Thus spontaneous breaking of chiral symmetry results in the end in the following effect: The almost massless u, d, s current quarks acquire the dynamical momentum-dependent masses Mu, d, $s(p)$ (constituent masses) and this is simultaneously connected with the occurrence of massless Goldstone bosons which are in nature the light (nearly massless) pseudoscalar mesons π, K, η.

The standard belief is that a linear confining potential provides the mechanism to bind constituent quarks to baryons and mesons. The confining potential is supposed to show some $1/r$-dependence for small distances and a linear rise r at large ones. However, in the real world with very light pions this cannot be correct because while increasing the distance between two quarks it is energetically favorable to create quark-antiquark pairs from the vacuum and to screen the confinement potential. The screening is so strong that in the end all that is left are constituent quarks with a dynamical momentum dependent mass $M(p)$ interacting with a mean field with the quantum numbers of the pseudoscalar Goldstone bosons, i.e. π, K and η. Actually there is not much freedom in formulating this in terms of a field theory since the interaction of pseudoscalar mesons with constituent quarks is to a large extent dictated by the chiral symmetry of QCD [10] yielding a well defined and more or less unique low-momenta effective theory.

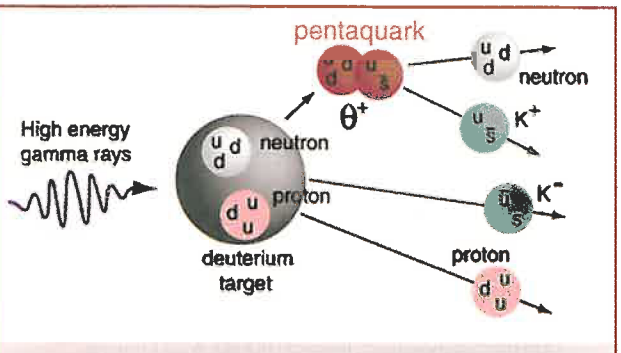
Relativistic mean field approach to the nucleon

The low-momenta quark-pion effective theory described above is a big step forward, as compared to the original formulation of QCD: it operates with the adequate degrees of freedom, namely the dynamically-massive quarks and the light pseudoscalar meson field [6]. The transition to these new degrees of freedom is similar to the transition from Quantum Electrodynamics (i.e. the microscopic theory of the atoms) to the electrons in a material, whose mass is not the original 0.511 MeV but a heavier effective mass, and whose most important interaction at the atomic "low energies" is not the Coulomb (read: gluon) field but rather the phonon (read: pion) exchange. Phonons are collective excitations of atomic lattices, and they are Goldstone bosons associated with the spontaneous breaking of the translational symmetry by the lattice. Pions are collective excitations of the QCD ground state (vacuum), and they are Goldstone bosons associated with the spontaneous breaking of chiral symmetry. Continuing the analogy, the Cooper pairing of electrons in a superconductor is due to phonon exchange that is much stronger than the Coulomb force between electrons (being actually a repulsion). Analogously, the binding of quarks into a nucleon can be explained as due to their interaction with the pion field. Although the corresponding low-momenta effective theory is a great simplification as compared to the microscopic QCD, it is still a strong-coupling relativistic quantum field theory which is solved and applied to light baryons in the chiral quark soliton approach (χQSM) [10] and variants of it [11]. In this approach the quarks with the momentum-dependent mass $M(p)$ move in a self-consistently generated pseudo-scalar mean field similarly to the Hartree-Fock potential in nuclear and atomic physics.

In contrast to the naive quark models, the χQSM is relativistic-invariant. Being such, it necessarily incorporates quark-antiquark admixtures to the nucleon. Quark-antiquark pairs appear in the nucleon on top of the three valence quarks as particle-hole excitations of the Dirac sea distorted by its interaction with the pion mean field [remember: the Dirac sea comprises all the levels with negative single particle energy since they always appear as solutions of the Dirac equation]. In addition there will be vibrations of the multitude of quarks moving in the self-consistent field and the reaction of the self-consistent field to this movement. These excitations should be described by means of relativistic random-phase-approximations, which, however, are not



▲ Fig. 2: The lowest baryon multiplets which can be interpreted as rotational states in ordinary and 3-flavour spaces, shown in the hypercharge-isospin Y-T_3 plane.



▲ Fig. 3: The reaction in which the Θ^+ was found by the HERMES collaboration at DESY

considered in the present context. In fact this mean field approximation with successive quantization of collective rotations in coordinate space and flavour space is known to be very successful, since it has described many properties of light baryons, as e.g. mass splittings and form factors of octet baryons, and parton distributions and generalized parton distributions of the nucleon.

Rotational excitations

A mean field solution as such does not provide the quantum numbers of the baryon yet. This is well known from nuclear many body physics, where e.g. the Hartree-Fock solution of a deformed nucleus has to be projected by Peierls-Yoccoz techniques on good angular momentum. There the results are multiplets characterized by the total angular momentum J and dimension of $d = 2J + 1$. The states inside a multiplet are $|J,K>$ with projection K of the angular momentum in the body fixed frame with $K = -J,...,+J$. In the present case for each J the members of each multiplet are characterized by two quantum numbers, i.e. the isospin T_3 and hypercharge Y. The reason lies in the more complicated structure of the symmetry group, which for three flavours of the quarks (up, down, strange) is SU(3). If one denotes the SU(3)-multiplets by their dimension and their angular momentum and parity one obtains $\left(8,\frac{1}{2}^+\right)$, $\left(10,\frac{3}{2}^+\right)$, $\left(\overline{10},\frac{1}{2}^+\right)$, $\left(27,\frac{3}{2}^+\right)$, $\left(27,\frac{1}{2}^+\right)$ ... They are ordered by increasing mass, see Fig. 2. The first two (the octet and the decuplet) are indeed the lowest baryonic multiplets in nature. They are also the only ones whose states can be composed of just three quarks in an orbital s-state, according to the quantum numbers. All other multiplets need explicitly the inclusion of the negative-energy single quark orbits (Dirac sea) and their distortion due to the interaction with the mean field. If one disentangles this distortion by means of the Thouless-Theorem it corresponds to $1p-1h$-excitations (or quark-antiquark excitations) with respect to the unperturbed Dirac sea. Hence e.g. the states in the anti-decuplet $\left(\overline{10},\frac{1}{2}^+\right)$ have structure with dominating components $uudd\bar{u}$ or $uudd\bar{s}$. Here the $uudd\bar{u}$ has in $\left(\overline{10},\frac{1}{2}^+\right)$ the same quantum numbers as udd of the ordinary octet and hence would fit into a pure 3-quark scheme. On the other hand, the $uudd\bar{s}$ is truly exotic, since it cannot be formed by three quarks and has no counterpart in the octet.

An interesting question is where to stop in this list of multiplets of the soliton. Apparently for sufficiently high rotational states the rotations become too fast: the centrifugal forces will rip the baryon apart. Also the radiation of pions and kaons by a fast-rotating body is so strong that the widths of the corresponding resonances blow up. Actually one needs to compute their widths in order to make a judgement. If the width turns out to be in the order of hundreds of MeV, one can say that this is where the rotational sequence ceases to exist.

An estimate of the width of the lightest member Θ^+ of the antidecuplet, shown at the top of the anti-decuplet, gave a surprisingly small result: $\Gamma_{\Theta^+} < 15\ MeV$. This result, obtained in the chiral quark soliton model, immediately gave credibility to the existence of the anti-decuplet and motivated the experimentalists to search for this new baryonic particle .

Prediction and observation of the Θ^+

In 1997 Diakonov, Petrov and Polyakov [2] summarized the results on the antidecuplet obtained in a collaboration between theory groups of the University of Bochum and of the Petersburg Nuclear Physics Institute in Gatchina. There were two striking features: Θ^+ had to be relatively light (1540 MeV) and surprisingly narrow ($\Gamma_{\Theta^+} < 15\ MeV$). This prediction has to be contrasted with naive quark model expectations where such a state should be as heavy as 1.7 - 1.9 GeV, broader than 100 MeV and of negative parity.

On the experimental side, from 1960's till early 80's there have been intensive searches for exotic $S = +1$ baryons in 1.7 - 1.9 GeV energy range with no convincing results. After 1986 the Particle Data Group stopped mentioning these searches. The 1992 partial wave analysis of the KN scattering data concluded that there might be broad resonances but, if there were any, they ought to be in a high-mass range. In fact, today we know that those KN-data are consistent with the present finding of the Θ^+ if this has a width of about one MeV [9].

In October 2002 T. Nakano [1] from LEPS collaboration reported the first evidence of the new baryon from the γC reaction. Independently, the DIANA collaboration led by A. Dolgolenko at ITEP, Moscow, looked into their K+Xe bubble chamber data. In December 2002 the group reported on the observation of a very narrow Θ^+. The next groups, including two CLAS experiments ($\gamma d \rightarrow pnK^+K^-$ and $\gamma p \rightarrow n\pi^+K^0\overline{K}^0$) at Jefferson Lab., knew about these two experiments, and gave very important confirmation using various reactions and final states [1], see fig. 3 for the reaction process at DESY. Later several experiments, mostly of higher energy, announced negative results [4].

It should be noted that all the experimental results (including the negative ones) came from reanalyzing the raw data of old experiments designed originally for other purposes. Recently LEPS (Spring8, Japan) and CLAS (Jlab, USA) have launched dedicated high statistics programs searching for exotic baryons. While the first results from LEPS confirmed the existence of Θ^+ in γd photoproduction, the analysis of ($\gamma d \rightarrow pnK^+\pi^-\pi^0$ and $\gamma p \rightarrow n\pi^+\pi^-K^+$) reactions at CLAS gave negative results. Preliminary as they are, these findings show our ignorance as far as the production mechanism of Θ^+ is concerned. Only when the full analysis including different final states is completed one can know whether these high statistics searches will invalidate or confirm the first low statistics sightings announced over the last 3 years. Therefore, one is now looking forward to the forthcoming results, for the issue to be finally resolved.

The decay width of Θ^+

All experiments giving evidence of the Θ^+ see that it is narrow, the most stringent bound being $\Gamma < 9$MeV. The indirect estimates [9] show that it can be actually as small as 1MeV or even less. If correct, Θ^+ would be the most narrow strongly decaying particle made of light quarks. Any theoretical model of Θ^+ has to explain the unusually small width first of all.

The Chiral Quark Soliton Model, which motivated the experimentalists, gave an estimate $\Gamma < 15$MeV [2]. To understand theoretically the small width it is helpful to go into a coordinate frame where it makes sense even for a relativistic system to talk

of the number of particles. This is the infinite momentum frame. In this system the baryon wave function falls into separate sectors of the Fock space: three quarks, five quarks (i.e. three quarks plus one quark-antiquark pair), etc. The difference between the ordinary nucleon and the Θ^+ is that the nucleon has mainly a three-quark component and a small five-quark component, while Θ^+'s Fock space starts from the five-quark component with small seven-quark admixtures.

For the calculation of the decay width of Θ^+ it is important that the Θ^+ decays only into $n + K^+$ and $p + K^0$ and the kaon is not an arbitrary meson but a (nearly massless) Goldstone meson. Hence, it is in some approximation sufficient to evaluate $g_A^{\Theta \to NK}$ as a transition matrix element of the axial charge between Θ^+ and the nucleon states. In the infinite-momentum frame the operator of the axial charge does not create or annihilate quarks but only measures the axial charge of the existing quarks. Thus, the matrix element in question is non-zero only between the pentaquark and the *five-quark* component of the nucleon, and this is known to be small. In addition there is a suppression in the overlap between Θ^+ and the 5-quark component of the nucleon and there are also some phase space arguments. A crude preliminary estimate shows that the Θ^+ width can be very small.

Summary

The discovery of the exotic Θ^+ with minimal quark structure $uudd\bar{s}$ may provide a sensation since, if confirmed, it is the first baryonic particle that cannot be composed of three quarks. The chiral quark soliton description of baryons has predicted the mass and an upper limit for the decay width of this particle prior to the experiments and in agreement with the present data. The model corresponds to a relativistic mean field description of the nucleon, where the quarks move in a self-consistent mean field of pionic and kaonic character. It uses an effective chiral Lagrangian based on spontaneously broken chiral symmetry of the QCD. In a natural way the chiral quark soliton model describes the well known lowest two multiplets $\left(8,\frac{1}{2}^+\right)$, $\left(10,\frac{3}{2}^+\right)$ and it predicts two more exotic particles being members of an anti-decuplet $\left(\overline{10},\frac{1}{2}^+\right)$ consisting of pentaquarks. The very narrow width of the Θ^+ can be explained by the small overlap of the 5-quark light cone wave function of the Θ^+ with the small 5-quark light cone component of the wave function of the nucleon.

If confirmed, Θ^+ will not only be a new kind of subatomic particle but will seriously influence our understanding of the structure of ordinary nucleons. ■

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Klaus Goeke, Michał Praszałowicz and Hyun-Chul Kim are professors of theoretical physics at their respective Universities. Both Michał Praszałowicz and Hyun-Chul Kim spend periods in Bochum, as Alexander-von-Humbold-Fellow and Postdoctoral Fellow, respectively. The authors have formed for several years a team with common publications using chiral solitonic models of the structure of the nucleon and light baryons with a focus on the newly discovered pentaquarks, the strange content of the nucleon and model-independent predictions of baryon properties. With their theoretical work they accompany experiments at COSY, ELSA, JLAB, DESY and CERN.

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Taking wax for a spin: microplates in an analog model of plate tectonics

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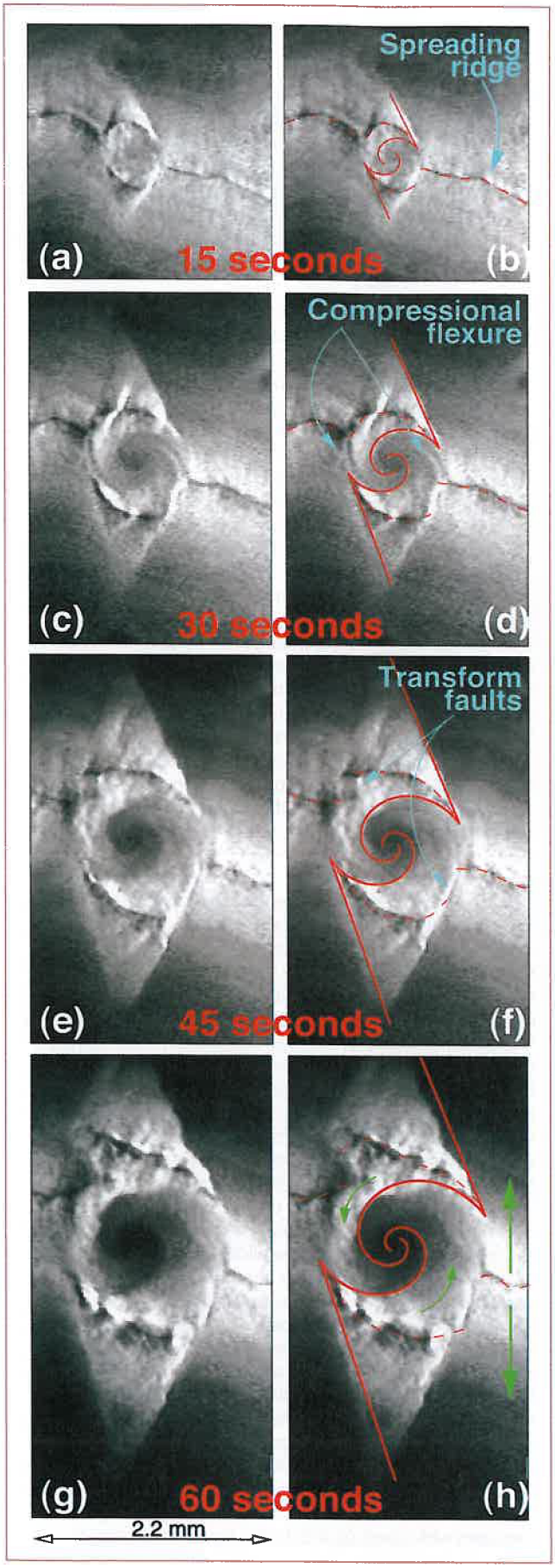
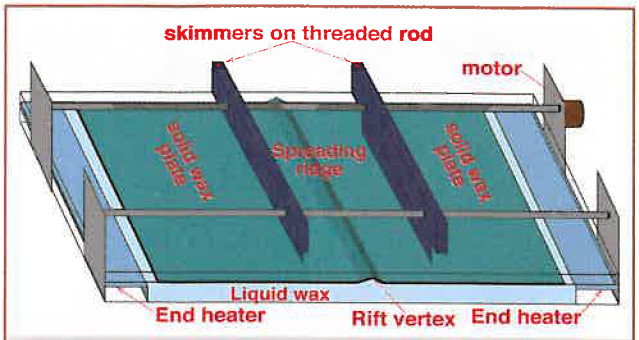
Watching the divergence of tectonic plates at a mid-ocean ridge is about as riveting as watching the grass grow; if you had the patience to stare for a year straight, you'd only see movement of a few centimeters. And, incidentally, with about four kilometers of water between the sea-floor and the closest ship, you'd have to be clever to figure out just how to get a view. Now consider the excitement of watching millions of years of geologic time unfold in seconds, in the comfort of your own laboratory. It's like one of those high-speed movies of clouds skittering across the sky – except that the clock is ticking about 10^{15} times faster than usual and you're watching dynamic processes that are impossible to observe in their natural setting. We've been whiling away geologic time just so, and not merely for entertainment.

In a paper recently published in the New Journal of Physics [1] we describe a wax analog model that simulates the divergence of two brittle lithospheric plates above a ductile mantle, exactly as it occurs beneath the sea at a mid-ocean ridge over millions of years (the lithosphere is the mechanical boundary layer at the surface of the Earth where the strength of rock increases dramatically). This work breaks new ground in quantifying the kinematic evolution of a curious tectonic feature of mid-ocean ridges, the microplate. Here we give a summary of that work.

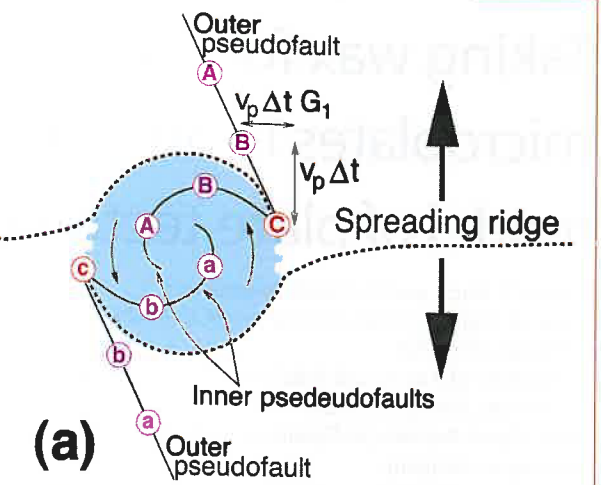
In a world where tectonic plates glide slowly from their origin at mid-ocean ridges to where they founder at subduction zones, microplates remain trapped between major plates on a mid-ocean ridge and spin (geologically speaking) about a vertical axis. They grow as they rotate by accreting lithosphere at their edges, leading to a characteristic spiral pattern of pseudofaults, visible to the trained eye through sonar surveys of sea-floor topography. This was geologic theory anyway, derived from the creative minds of marine geophysicists who had never actually watched the sea-floor in motion [2]. We quantified this theory, applied it to detailed

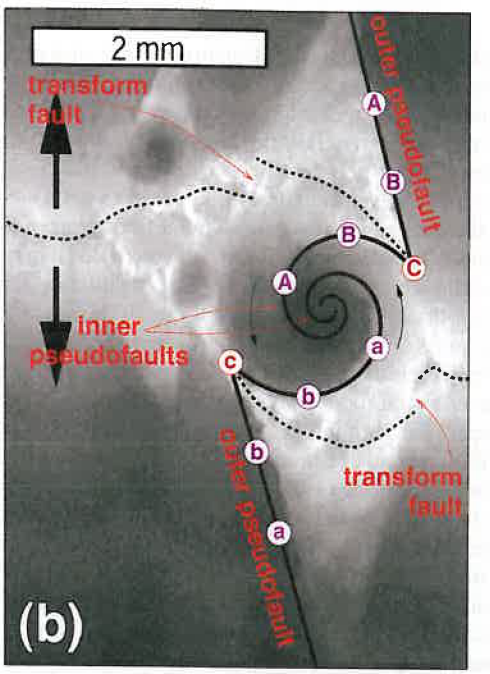


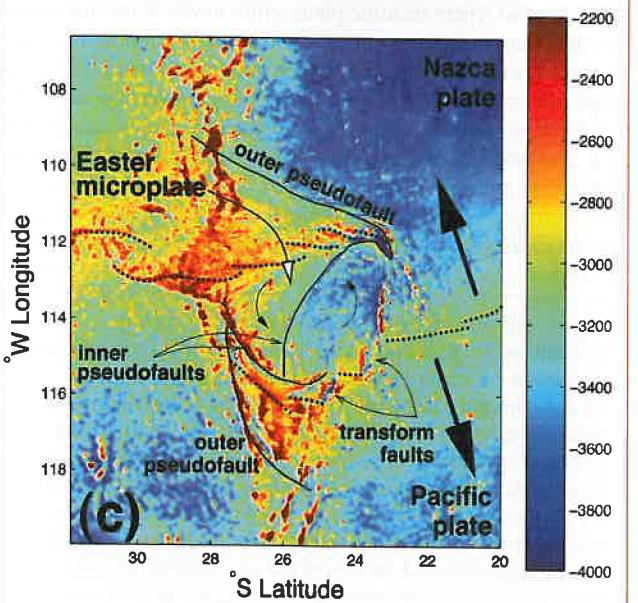
► **Fig. 1:** Time series of images showing a growing microplate at 15 second intervals. Spreading is to the top and bottom of each image at a half-rate of 35 μm/sec. **(Left column)** Images of the microplate. **(Right column)** Images identical to those in the left column but with pseudofault pairs and spreading ridge traces overlayed in red. The inner pseudofaults were generated using equations described in the appendix of [1]. Ridge traces were drawn by hand. Blue annotations indicate morphological features. Green arrows show the direction of motion of the main plates and the direction of microplate rotation. The figure is from Ref. [1]



▲ Fig. 2: Schematic diagram of the experimental setup. A rectangular tank of size 114 x 36 x 10 cm³ is filled with Shell Callista 158 wax which melts at about 72° C. The mechanical properties of micro-crystaline wax are brittle at room temperature and paste-like close to the melting point. No detailed mechanical measurements are performed. The tank is heated from below to (80.0 ± 0.05)°C and cooled from above by a constant flow of air at (12.0 ± 2.0)°C. The weakly turbulent refrigerated air flow is directed vertically downward. Before each run the wax is brought to temperature equilibrium at which a layer of solid wax is present on the surface. Skimmers embedded in the solid wax are attached to a threaded rod that is driven by a micro-stepping motor. A detailed description of this setup has been previously published [11]. The rift is initiated with a straight cut through the wax, perpendicular to the spreading direction. Divergence at this cut causes liquid wax to rise into the rift and solidify. Illumination from below permits us to image the plate thickness at the rift from above using a video camera. As the wax plate thickens it scatters more of the transmitted light and appears darker. In images of wax microplates shown here, spreading is toward the top and bottom of the image and the rift appears as a dark line. The figure is from Ref. [1]







▶ Fig. 3: Three microplates: schematic, wax and Earth. Dashed lines show the position of the spreading rift. Solid lines mark the inner and outer pseudofaults. Large black arrows show the spreading direction. Small black arrows show the sense of microplate rotation. **(a)** Schematic diagram illustrating the kinematics of microplates according to the Schouten model. The letters indicate points on the pseudofaults that were formerly at the rift tips, showing how the microplate grows with time. The current positions of the rift tips are marked as (c) and (C). The linear outer pseudofaults indicate a constant radial growth rate, which in turn implies a logarithmic spiral inner pseudofault. **(b)** Image of a wax microplate with model fit and rift tip markers overlayed as in (a). Transform faults are labeled on the image. They are located laterally across the microplate from the rift tips. Note the brighter, thinner wax triangles above and below "south" and "north" of the microplate. The width of the thin-plate triangular region at any distance from the ridge shows the approximate diameter of the microplate at a time in the past. **(c)** Bathymetry of the Easter microplate [12]. Colors denote elevation with respect to sea level; the color scale saturates at a minimum depth of 2200 m and a maximum depth of 4000 m. The Easter microplate is about 400 km across and is currently rotating clockwise at about 15°/Ma; over its lifetime of 5 Ma it has rotated about 95° [2]. Rift and pseudofault locations by D. Naar, modified from Naar and Hey (1991) [13]. Note that this image has been rotated counterclockwise and reflected across the *y*-axis so that the orientation and sense of rotation of the microplate is consistent with panels (a) and (b). The figure is from Ref. [1]

observations of their kinematic model and found excellent agreement, proving a connection between the observed morphology of microplates and their tectonic evolution. In Figure 1 we show that wax microplates obey the same relation between spreading rate, growth rate and spiral pseudofault geometry as their oceanic cousins. Our wax-to-Earth scaling relations indicate that the dimensions of wax microplates are consistent with estimates for oceanic microplates [2, 3]. Through close observation (e.g. Figure 4), we have developed a theory for the nucleation of overlapping spreading centers, known to be the precursors of microplates in wax and on Earth.

Microplates were discovered on the ocean floor in the early 1970s through surveys of their magnetic anomalies, seismicity and topography [4, 5, 6]. An explanation of their peculiar geometry and possible modes of formation were proposed shortly afterward [7]. During the 1980s microplates were recognized as an important tectonic feature of mid-ocean ridges, particularly the East Pacific Rise (EPR) [8] and much work was done to comprehensively map their structure (e.g. [9]). At least 12 paleo- and active microplates are known to exist in the Pacific Basin and additional ones are suspected to exist based on patterns observed in altimetry data [D. Naar, pers. comm., 2004]. The Easter microplate, shown in Figure 3c, sits on the EPR near 25°S between the Pacific and Nazca plates. High-resolution maps enabled the development of kinematic models [2] but due to the difficulty of interpreting sea-floor data, these models have not been conclusively verified. Furthermore, important questions regarding the origin of microplates and their eventual death have not been answered. Current numerical simulations cannot reproduce the coupled fluid-solid deformation processes responsible for microplate nucleation and growth at mid-ocean ridges. On the other hand, published results from a wax analog model yielded the first observations of overlapping spreading centres (OSCs), morphological precursors to microplates, before their discovery on the sea-floor [10]. We demonstrate that wax models still possess significant potential to provide insight into this long-standing problem.

Experiments

Our experimental setup is shown in Figure 2. The experiment is initiated with a cut with a sharp knife to divide the wax surface into two plates. Activating the motor caused the skimmers to diverge, dragging with them the two wax plates and causing fluid wax from below to upwell into the rift between the plates, just as ductile mantle rock upwells from beneath a mid-ocean ridge. The rift remains frozen over as long as the spreading of the plates is slow enough to accomodate the rise and solidification of molten wax from below.

Although the wax rift is initiated with a straight cut, it evolves and changes its morphology, closely mirroring the morphological signature observed in sonar images of the mid-ocean ridge. Three distinct morphological regimes were observed for ranges in spreading rate of an initially orthogonal rift. At slow half-spreading rates (~ 10–30 μm/sec) the straight rift is stable and forms a topographic low. At moderate rates (~ 30–60 μm/sec) the straight rift becomes unstable and overlapping spreading centres (OSCs) and microplates form, evolve and die on the ridge. In this regime the ridge has little or no relief. At higher half spreading rates still, the microplates lose their internal rigidity and become, in an intermediate stage, fault gouge zones and finally (> 70 μm/sec) transform faults at a ridge that forms a topographic high. In the work published in NJP we focused on the microplate regime. Movies and further information on the other regimes can be found at http://milou.msc.cornell.edu/ waxtectonics.html. There it is shown that experiments using other waxes can capture the dynamics of freezing lava lakes.

Tectonics in miniature and warp speed

To interpret the wax tectonics experiments we must consider how experimental distance and time scale from experiment to Earth. A time scaling can be determined by comparing rotation rates: a mature oceanic microplate rotates 20° in about 1 Ma while a wax microplate completes this rotation in about 5 seconds. This means that the experiment is sped up by a factor of approximately one billion. In the NJP article we have also shown that 1 mm in the wax experiment scales to about 50 km on Earth. This corresponds to shrinkage by a factor of 50 million. Indeed, the scales in the wax experiment are almost too small and too fast.

Microplate model confirmed

We have shown [1] that a kinematic model of microplate evolution proposed and applied to the Easter microplate by Schouten *et al.* [2] can explain the data. The Schouten model states that the rigid motion of a microplate is like that of a ball rotating between two parallel, moving plates. Unlike the ball, however, a microplate grows by accreting young lithosphere, as shown schematically in Figure 3a. In Ref. [1] we derived a mathematical formulation of the Schouten model that we used to calculate the predicted shape of the inner pseudofaults for an image of a mature wax microplate. The fit depended only on a single free parameter, the diameter of the microplate when it began to rotate rigidly. All other parameter were determined by the experiment. Once one image had been fitted it was possible to use the formulae to calculate back in time. This way it was possible to to test also the dynamical predictions of the Schouten model. Figure 3 shows an example of predicted and observed morphological time-evolution. Clearly, a similar time-series comparison for Earth is impossible as we would need to wait 500,000 years to acquire the data. Studies, however, have compared the predictions with the current shape of oceanic microplates and found reasonable agreement [2, 3].

How are microplates born?

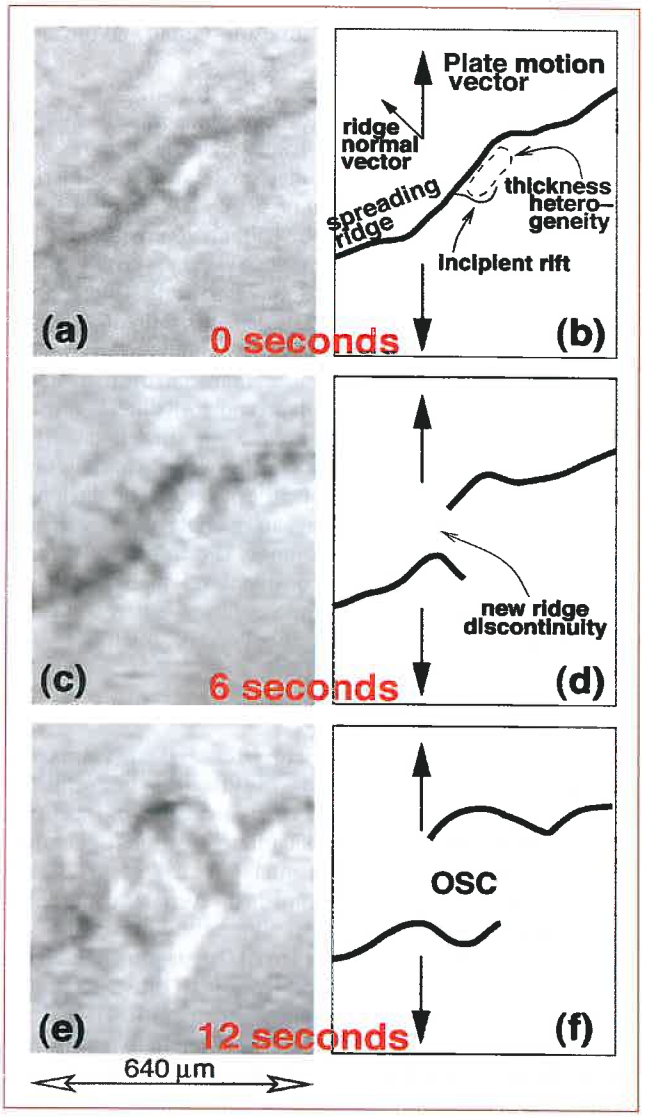
Like oceanic microplates, wax microplates originate from overlapping spreading centers (OSCs) which nucleate frequently on the spreading rift. We observed [1] that nucleation of wax OSCs occurs predominantly on ~200-300 micron sections of obliquely spreading rift, where the rift normal is about 45 degrees from the spreading direction. The diminished divergent component of spreading across these segments allows the rift axis to freeze across, introducing a discontinuity in the rift as shown in Figure 4. This results in a local stress field tending to cause the propagation of rift tips into an overlapping geometry [14]. The rift tips will only propagate in this manner if the strength to tensile fracture of the adjacent lithosphere is small relative the the strength of the frozen rift. If, on the other hand, the adjacent lithosphere is too strong to be fractured by rift tip propagation, deformation and faulting will remain localized on the rift centre. A muted strength contrast might be expected at fast spreading ridges where the adjacent lithosphere is thinner and weaker than at slow spreading ridges, consistent with the distribution of microplates on Earth. Furthermore, if applicable to Earth, this freezing-over mechanism of nucleation might explain the formation of OSCs on transform faults that have gained a component of divergence after a plate-motion change or plate-boundary reorganization [15]. This reasoning equally applies to the wax, although we have not experimented with changes in spreading direction.

Conclusion and outlook

In Ref. [1] we have shown that a wax model of sea-floor spreading, under the right conditions, produces tectonic microplates that

evolve in time according to a kinematic model designed for oceanic microplates. This finding suggests that wax microplates are a good analog formicroplates on the ocean floor and reinforces the validity of the kinematics prescribed by the Schouten model [2]. Futhermore, the presence of microplates in our analog model indicates that on Earth, microplates are a lithospheric phenomenon not dependent on special conditions or processes in the underlying mantle. Other similarities between wax and Earth suggest that thesemodels have potential to advance our understanding of microplates and other sea-floor spreading phenomena. For example, inferences drawn from repeated observation of the nucleation of wax microplates may apply to the birth of their oceanic counterparts.

Clearly the work so far is only the beginning. The wax tectonics experiments have the advantage that they are much simpler than Earth and that they can be made quantitative in terms of material properties, the measurement of the thermal and flow fields, and possibly the stress field. They can be used to quantitatively test numerical models that later, in a refined form, can be applied to Earth or other planets. ■



▲ Fig. 4: Nucleation of an OSC, precursor of a wax microplate. (Left column) Time series of images at high magnification. (Right column) Interpretive drawings mapping the evolution of the rift into an overlapping geometry. Note that interpretation is based on the movie from which these images were drawn. (a-b) Time $t = 0$. A section of rift with normal vector oriented 45 degrees from the spreading direction. The OSC nucleates around a thickness heterogeneity at the rift which appears as an elongate white blob. (c-d) Time $t = 6$ seconds (~ 1.2 Ma). A rift discontinuity appears and the disconnected rifts begin to overlap. (e-f) Time $t = 12$ seconds (~ 2.4Ma). Rifts are overlapping around an enclosed region with a diameter of about 300 µm. This OSC subsequently develops into a rotating microplate. The figure is from Ref. [1]

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Freak waves: just bad luck, or avoidable?

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JANUARY 26, 2005
Coast Guard sends help to stalled 'Semester at Sea' ship
A 50-foot wave smashed through the bridge windows of the 591-foot MV Explorer around 2:30 p.m., pouring saltwater over electrical components on board and disabling all four of its engines, officials said.

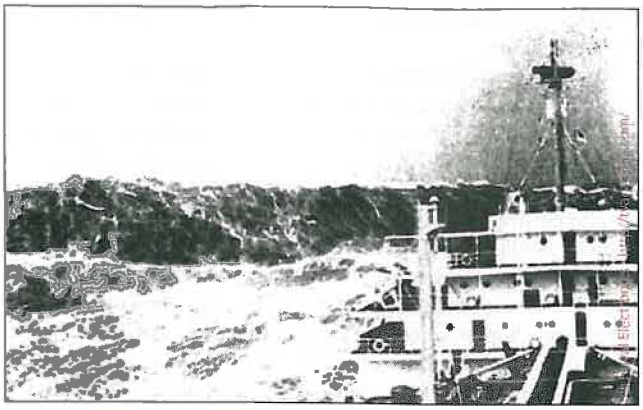
FEBRUARY 14, 2005
Giant wave hits cruise ship
A rescue operation has been carried out in the Mediterranean after a cruise liner issued distress signals off the coast of Minorca. The ship was hit by ferocious waves that smashed windows on the bridge as the ship was sailing from Tunis to Barcelona. The spokesman said water poured in, knocking out electric power, stopping the engine and leaving the ship adrift with no communications. (www.itv.com)

APRIL 16, 2005
'Freak' wave rocks cruise
'Norwegian Dawn, an opulent ocean liner almost 1,000 feet long, limped into Charleston, S.C., yesterday afternoon after it hit vicious seas in an overnight storm off Florida - then was creamed by the rogue wave after dawn." (NY Daily News)

Since the first of the year, three large cruise ships have been disabled by freak waves. All were sailing in moderate to heavy seas when the big one hit: the MV Explorer in the Pacific January 27 with 600 students aboard, the Voyager February 14 in the Mediterranean, and the Norwegian Dawn off the coast of Florida April 16. Windows as high as 100 feet above the waterline were damaged, and in some cases the bridge was compromised by seawater, leading to electronics problems and engine shut down.

Is this an unusual spate of freak waves? Probably not! The tragedy of the 2004 Tsunami has sensitized the press and the public to unusual events in the sea. These events would have received much less attention if they had happened before the Tsunami. For example, during a three week period when satellites were measuring sea surface heights, between February and March 2001, two stout cruise boats, the Bremen and the Caledonian Star, had their bridge windows demolished by 30-metre freak waves in the South Atlantic, with apparently less media attention. The Bremen was left helplessly drifting without navigation or power for two hours. In February 1995 the cruiser liner Queen Elizabeth II met a 29-meter high freak wave in the north Atlantic.

Freak waves are ultimately wind generated and have nothing to do with Tsunamis, claiming "only" perhaps one or two hundred souls per year. Weaker boats than cruise ships and military vessels, e.g. tankers and container vessels, often break in two when they meet a freak wave (Figure 1a), often described by surviving witnesses as "a hole in the sea followed by a wall of water". The bow buries itself in the wall, the wave breaks over the unsupported midships, snapping the vessel in two (Figure 1b) and often sinking it in a few minutes. No radio for help (the electronics is the first to go), no debris, no black box. The news media are not triggered during the slow realization that a cargo ship with 10 or 20 seamen is missing. It's been happening for thousands of years, and it happens now at an estimated one ship every month or two.



▲ **Fig. 1a:** A rare photograph showing the "wall of water" approaching a ship. The "hole in the sea" is presumably out of sight just in front of the "wall".

Well before the 2004 Tsunami hit, scientific interest in freak waves picked up as photographic, ocean buoy, and satellite evidence mounted, finally giving credence to five or more thousand years of surviving sailor's yarns. The most convincing call to action however was the European Union MaxWave project [1], which used synthetic aperture radar (SAR) data to analyze 30,000 sea-surface images of five by 10 kilometers each. The data, taken over three weeks in 2001, revealed more than 10 freak waves - far more than expected. One estimate from this data suggest that 50 or more freak waves are stalking the seas right now as you read this. This work is spurring a much larger inventory of the sea surface called WaveAtlas.

Much theoretical and experimental progress has been made, especially on the issues of nonlinear evolution of waves, which can amplify wave heights and alter their shape to more menacing, breaking walls of water. The biggest question remains, however: how often and under what conditions should freak waves be expected?

Freak waves have a technical definition, beginning with the significant wave height (SWH), which is the average height of the highest 1/3rd of the waves in a long sample. Freak waves are defined as waves bigger than 2.2 times the SWH.

For anyone familiar with wave behavior, the first thing that comes to mind as an explanation for freak waves is an unlucky constructive interference of independent wavesets moving in slightly different directions, with somewhat different wavelengths, etc. Indeed such bad luck is certainly possible and this idea led to the first and most predictive of all freak wave theories, the venerable Gaussian seas model of M.S. Longuett-Higgins[2]. A storm does not produce a single plane wave, but the idealization of a random superposition of many plane waves with a mean direction of travel and some dispersion in angle, wavelength, and amplitude was introduced. The Central Limit Theorem applies; the distribution of amplitudes is Gaussian.

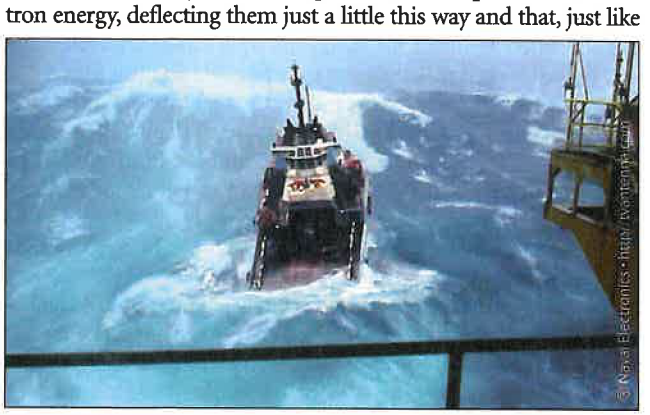
The danger a wave poses is not merely a matter of its height. A 40 foot wave in a sea with SWH of 40 feet is likely to be far less dangerous than a 40 foot wave with SWH 16 feet. The reason is the steepness. A SWH = 40 foot sea is likely to have a much longer wavelength than a SWH = 16 foot sea, so that the sudden appearance of a 40 foot wave among the 16 footers means a very steep wave. Steep waves tend to break, which makes them more dangerous to any ship or boat.

There is no widely accepted theory of how freak waves form in the open ocean.

Three categories of models predominate: (1) Gaussian statistical (the "unlucky" constructive addition mentioned above) (2) refraction leading to focusing of wave energy, and (3) nonlinear growth and steepening of waves. The trouble with the Gaussian model is that freak events it predicts are too rare compared to present estimates.

The natural place to turn to generate more freak events is through nonlinear growth of waves. There is no doubt whatsoever that nonlinear processes are important to water wave physics. Any breaking wave is exhibiting nonlinear behavior. The slow evolution from short chop produced by wind to long ocean swell (which can sometimes travel faster than the wind that originally provided their energy) is caused by the Benjamin-Feir instability [3], a well established nonlinear wave process. Much work has gone into water wave evolution, governed by a variant of the nonlinear Schroedinger equation of quantum physics (recently playing a big role in Bose-Einstein condensed matter [4,5]). Presumably these nonlinear events are relevant for the minutes or moments just prior to a wave becoming dangerous. It seems likely that this sort of nonlinear evolution, in which a wave can grow at the expense of its neighbors, can contribute to some freak wave events. One difficulty with this theory however is a lack of predictive power: what triggers the mechanism of nonlinear growth? If always operative, it seems nonlinear growth would put freak waves everywhere in all kinds of seas.

The crucial link may be the known association between current eddies and freak waves. Ocean eddies are ubiquitous but the most well known strong eddy regions, like the Aguhlas current off the coast of South Africa, and near the Gulf stream, are also famous sites for freak waves. The mechanism must have something to do with refraction of the waves. Waves of any sort refract when they propagate in a medium moving at different velocities in different regions. The refraction was worked out for water waves in general by Peregrine [6], but more recently White and Fornberg [7] pioneered a model that specifically involves waves traveling through random fields of current eddies. The generic result is a pattern of caustics where wave energy concentrates; these caustics are infinitely sharp and strong if ray tracing of the waves is carried for a single incident direction. The compelling images given in the White and Fornberg paper were a shock to this author, because they looked exactly like the ray tracing patterns for electron waves in a special class of semiconductor called a two dimensional electron gas (2DEG), computed in our group. Electrons in these micron-sized devices must negotiate random potential fields filled with hills and valleys, whose height is small compared to the electron energy, deflecting them just a little this way and that, just like the water waves in eddies on a scale 10^8 times larger (Fig. 2). The reason for the similarity is a universal pattern seen in ray trajectories when passing through a random weakly deflecting medium. The universal structure is called a cusp caustic, (Fig. 3); many generations of these cusps form downstream, of even more correlation lengths of the random interaction leads to the universal branching pattern which was the subject of Refs.[8] and [9].



▲ Fig. 1b: A ship broken up by a freak wave with another large wave approaching.

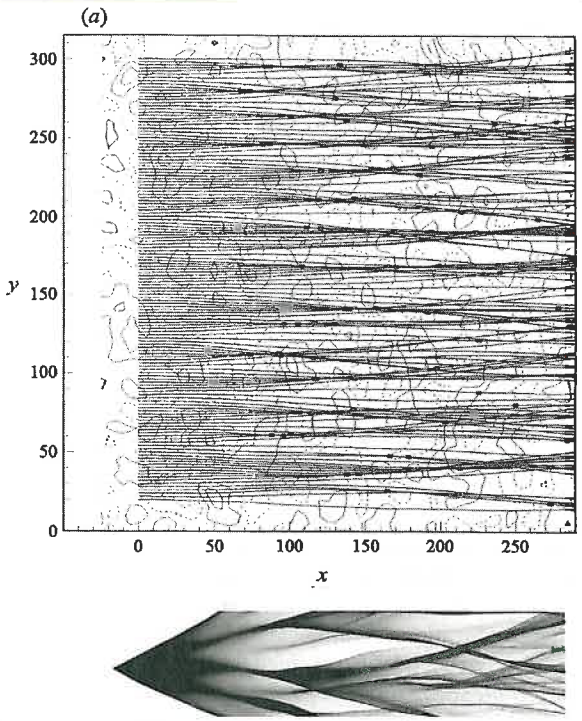
The White and Fornberg work came under criticism [10] since, unrealistically, they used only a single incident plane wave in their studies. A good analogy is a magnifying glass outdoors. On a sunny day, with strongly directional rays, the focal point is very bright. So much energy is concentrated there that waves are constantly being produced with high amplitudes. Try the same on a cloudy day, with rays coming from all over the sky, and the focal region is ill defined and hardly any brighter. The critics assumed correctly that the caustics would wash out and the huge waves that were predicted to occur at the caustics would not materialize.

Or would they? It occurred to this author that, while the caustics would indeed wash away, what would remain would not be a uniform energy density. It is not widely appreciated that truly Gaussian seas must have a *uniform* underlying energy density, even though this is a simple point. What would happen to the statistics when there is, say, a factor of 2 or 3 variation of energy density giving rise to hot spots of suddenly higher density where wave energy is concentrating?

The answer is: almost nothing happens to the statistics, unless you are interested in *rare events!* The SWH is almost unchanged, averaging over the hot spots, and on a linear scale the Gaussian statistics looks almost unchanged. Even the fourth moment of the Gaussian versus the fourth moment of the nonGaussian patchy hot spot density (the so-called Kurtosis) is almost unaffected. However, very large wave event probabilities can be several orders of magnitude larger than the Gaussian sea model, just the sort of effect we are looking for, even after averaging over 20 percent variations in direction and wavelength. (This shows up strongly in very high moments, like the 20^{th} or 24^{th}).

Figure 4 shows ray tracing and wave propagation on a random velocity field, using the linear Schroedinger equation. (Indeed although the underlying ray tracing is "nonlinear dynamics" in the sense of classical physics, the wave propagation, done independent of any ray tracing, is perfectly linear, meaning that the equations used depend only on the wave ψ and its derivatives, not on ψ^2, etc.) The caustics are indeed smoothed out, but the remaining high energy hot spots have become loci for extreme events, recorded in color for a long run passing many waves over the whole region, with again 20 percent variations in direction and wavelength for realism. The high energy hot spots are clearly visible in either the ray tracing over many ray paths (so many that they form a smooth density) or time averages of wave energy density.

As one might expect, there is a figure of merit which tells us how close to the "cloudy day" limit we are, using the focusing lens analogy given above. The more spread out the wave directions to begin with, the safer we are from freak waves. This might go against intuition, in that confused seas (seas with a wide range of directions of propagation) are already unruly and seeming ready to spring a surprise. But the lens effect will be small and the washout of the caustics very strong in already confused seas. The statistics of the wave heights is actually independent of the mix of wave directions in a purely Gaussian context. So the most dangerous situation is a fairly collimated sea impinging on an eddy field. Although the caustics may still be washed out, the high energy hot spots remain statistically very dangerous. Even averaging over the low energy and high energy hot spots gives large enhancements of freak wave formation.



▲ **Fig. 2:** A figure from White and Fornberg, Ref. 7, showing ray tracing of the wave propagation through a field of random current eddies. All the rays started out parallel, corresponding to a single initial propagation direction. Note that the typical focal distance where the first caustics (accumulations of rays) form is several times longer than the breadth of a given eddy, while the distance between different first caustics is about the eddy size.

The figure of merit is measure of danger, called the "freak wave index" γ. The defining equation is

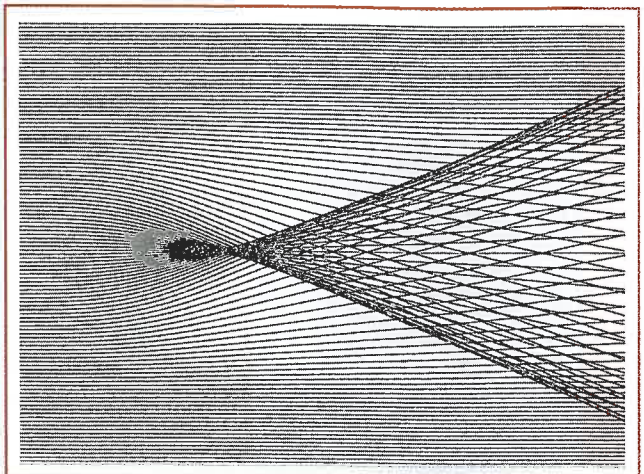
$$\gamma = \delta\theta/\Delta\theta,$$

where $\Delta\theta$ is the initial spread of angles of the waves incident on the eddies, and $\delta\theta$ is the angle of deflection of the rays when they reach their first focal point. This latter is a property of the wave velocity and the eddy field. For typical parameters used by White and Fornberg, this index lies between 1.5 and 3, with 3 being very dangerous and 1.5 less dangerous.

The idea of our new work [11] is suspended between Longuett-Higgins on the one hand, and White and Fornberg on the other. Like Longuett-Higgins's original work, the appearance of a rogue wave is a statistical event, not a certainty as with White and Fornberg's caustics. Indeed we assume *locally* Gaussian statistics, but averaging over the high hot spots strongly enhances the wings of the resulting overall distribution. On the other hand White and Fornberg's statistical refraction through current eddies, with the additional directional averaging, give energy hot spots which are not part of Longuett-Higgins's model.

The nonlinear mechanisms surely play an important role, since once a freak wave starts to form in the way we have suggested ("bad luck at hot spots", essentially) nonlinear processes will surely come to play a more critical role with the large waves thus generated. Perhaps the "hot spot + bad luck" mechanism is the trigger necessary to initiate important nonlinear events.

By combining aspects of both the refraction model and



▲ **Fig. 3:** The ray trace pattern (a cusp caustic) as initially parallel rays pass through a focusing region. The focal distance varies with the distance of approach from the center, i.e. as in a "bad" lens with spherical aberration. By averaging over incident directions, the cusp singularity will be softened but not washed away completely.

Gaussian random addition it appears that we have an effect that is either a major cause of rogue waves, confirming their association with current eddies for example, or it has to be debunked in some way involving new physics. Either way it is going to be an interesting ride.

One can envision the day when, by studying currents eddies (say with Doppler satellite radar) and wave propagation and height data, the marine forecast could say "the freak index is 2.3 today in a region 100 km south of a line...; the probably of a ship encountering a dangerous freak wave is 2 % and that region should be avoided".

The bottom line, at least in the author's opinion, is that the original explanation of an "unlucky addition of waves" is partly true, but that the odds get much worse when there are energy hot spots around, a trend that seems to agree with the prevailing notion that something out there is responsible for a lot more freak waves than were thought to exist only a few years ago. ■

About the Author

After receiving a Ph.D. in Chemical Physics at Harvard in 1973, Heller took positions at UCLA, Los Alamos, University of Washington,and since 1993, Harvard University, where he is Professor of Physics and Professor of Chemistry. Heller's research focuses on few body quantum mechanics, scattering theory, mesoscopic physics and quantum chaos, ultracold matter, and now freak waves at sea. Heller enjoys sailing off the British Columbia coast aboard his sailboat "Resonance", but thankfully he has never seen a freak wave.

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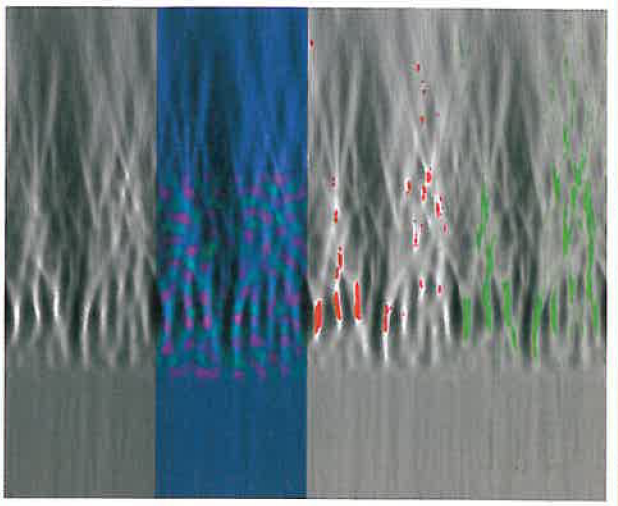

▲ Fig. 4: This figure collects data from a long run with "Longuett-Higgins" Gaussian seas impinging from below on an eddy field, here represented as a potential force field. In the left panel, the average energy density of the waves is plotted in grayscale, with lighter regions having higher energy density. The potential field (deflecting the rays) is shown as hills (green) and valleys (purple) in the next panel. Severe freak wave events (waves six or more standard deviations computed from the mean Gaussian) were recorded as red in the next panel; note that there are no events before the refraction starts and some after it has ended. Finally the 4.4 σ events are shown in green in the right panel; there are a few of these before the refraction but many more after it starts and beyond.

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Is Science Education Relevant?

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In this article a range of results from the ROSE-project (Schreiner & Sjøberg, 2004, 2005) are reported with particular focus on the question of whether science education is relevant to 15-year olds in three OECD countries: Japan, England and Denmark. Based on an analysis of the available data, four dimensions of science and science class relevance are investigated. These dimensions will be referred to as the *Everyday life dimension, the Future- and career dimension,* the *Science, technology and society dimension* and finally the *Science class content dimension.* Finally the results are discussed in a broader perspective.

Science education in Europe at all levels is facing significant challenges. Firstly; it is often argued that all citizens must be scientifically literate in order to participate competently in a modern knowledge-based society where science and technology have major impact on everybody's life. On a daily basis, we all face debates in media and in the political arena about socioscientific controversies such as global climate change, the use of gene manipulated organisms in food products and cloning of human beings (Kolstø, 2001). The need for a broadly based and competent participation in decision making concerning these issues demands of the educational system that science be taught in ways which make it interesting and relevant to all students (Andersen et al., 2003; Millar & Osborne, 1998). Secondly, there is concern that European countries will find it increasingly more difficult to meet the need for a knowledge- and technology-based society to produce a high proportion of trained citizens capable of conducting research, development and education within science and technology (The High Level Group on Increasing Humans Resources for Science and Technology in Europe, 2004).

In order for European educational systems to meet these challenges science educators and scientists need a qualitatively deeper and more solid evidence-based understanding of young peoples' attitudes towards science, technology and school science. Hence the ROSE-project and this article.

The ROSE-project

The ROSE-project is an international comparative study led by Professor Svein Sjøberg along with Ph.D.-student Camilla Schreiner from the University of Oslo in collaboration with science education researchers from 40 other countries representing all continents except North America. In each country a geographically and socio-economically representative sample of 15-year old students[1] has filled out the ROSE-questionnaire, which consists of 250 statements (items) to which the students were asked to respond on a four-point Likert scale (see below). The complete international data set is not yet fully released, but for the purpose of the present article permission has been granted to publish some international results.

1 Cf. (Schreiner & Sjøberg, 2004) for the sampling procedures.

Item	Statement	Mean			Mean difference		Country
		Girls	Boys	All	G-B		
F07	The things that I learn in science at school will be helpful in my everyday life	2.50	2.70	2.60	-0.20	Sig.	Japan
		2.71	2.68	2.68	0.03		England
		2.35	2.37	2.37	-0.02		Denmark
F09	School science has made me more critical and sceptical	1.78	2.09	1.94	-0.31	Sig.	Japan
		2.15	2.33	2.24	-0.18	Sig.	England
		2.05	2.15	2.10	-0.10		Denmark
F10	School science has increased my curiosity about things we cannot yet explain	2.22	2.67	2.45	-0.45	Sig.	Japan
		2.61	2.79	2.70	-0.18	Sig.	England
		2.32	2.38	2.36	-0.06		Denmark
F11	School science has increased my appreciation of nature	2.62	2.57	2.59	0.05		Japan
		2.26	2.33	2.30	-0.07		England
		2.33	2.24	2.29	0.09		Denmark
F13	School science has taught me how to take better care of my health	1.96	2.18	2.07	-0.22	Sig.	Japan
		2.68	2.60	2.64	0.08		England
		2.34	2.24	2.30	0.10		Denmark

▲ **Table 1:** Student mean scores and gender differences for the five items defining the analytical dimension "Everyday life relevance of science classes"

International comparative studies represent a prominent trend in modern educational research. Within the field of science education, the TIMSS-studies (Trends in Mathematics and Science Studies) and lately the OECD PISA-studies (Programme for International Student Assessment) are the most elaborate, important and influential in terms of impact on educational policy. Broadly speaking, the aim of TIMSS is to assess to what extent (lower secondary school) students have achieved certain curricular goals within mathematics and science, whereas the PISA-studies attempt to obtain a measure of how well 15-years olds are able to handle challenges related to mathematics and science in a modern, complex and knowledge-based society. Both studies focus on *cognitive* factors, however, i.e. students' skills, competencies or level of scientific and mathematical literacy.

In contrast to these studies, the ROSE-project is focused on *affective* factors that influence students' participation in science classes and their current and future engagement in science and technology. ROSE is an acronym for *Relevance Of Science Education* and as indicated by the title, the aim is get insight into the perspective of *learners* on science, technology and science education. In most countries the science curriculum at all educational levels is uniquely defined by the proper authorities: legislative authorities, local boards at educational institutions and the teachers. There are, of course, good reasons for this. Society, the business world and the scientific communities have a range of legitimate interests in students acquiring particular skills and competencies. Until recently, however, we have failed to acknowledge and attempt to map thoroughly the learners' attitudes towards their science classes and towards science and technology in general. At least two reasons to do so can be mentioned. Firstly, we want to teach (science) for citizenship and thus put an emphasis on rational arguments, debate and consensus-making. This can only be done if we also acknowledge the learner's perspective and voice in a particular teaching situation. Secondly, and more pragmatically, we know that a positive attitude towards the content and the activities in a teaching situation is a fundamental prerequisite for a particulars learner's cognitive yield.

A range of studies of students' attitudes towards science using different methodologies have been performed during the last decade or so. A thorough review of these studies can be found in (Osborne, 2003), in which a range of factors known to influence students' attitudes towards science are presented and discussed. It is also pointed out that "the concept of attitude towards science is somewhat nebulous, often poorly articulated and not well understood" (Osborne, 2003). Are we talking about the opinion of the value of science, the motivation or anxiety towards science, the enjoyment of science, etc? Also, which kind of expression of interest or attitude are we dealing with? Is it expressed by a concrete action or a choice which significantly affects the individual's life (such as the choice of study at the tertiary level of education) or is it merely an expression free of responsibility, e.g. in a questionnaire?

In this article the focus will be on different dimensions of relevance of science classes in lower secondary school as seen from the perspective of 15-year olds and expressed as a degree of agreement upon a range of statements featured in the ROSE-questionnaire.

The ROSE questionnaire

The background for the ROSE-study, the objectives, the process of developing the questionnaire and thorough methodological discussions are presented in the background report for the project (Schreiner & Sjøberg, 2004). In the present article a few key elements concerning the questionnaire are presented, whereas the reader is referred to the background document for further details.

The ROSE-questionnaire covers the following sections of items (the number in parenthesis refers to the number of

questionnaire items belonging to a particular section) in addition to background information about the respondents:

ACE	What I want to learn about (108)
B	My future job (26)
D	Me and the environmental changes (18)
F	My science classes (16)
G	My opinions about science and technology (16)
H	My out-of-school experiences (61)

Examples of items from the questionnaire cover: "Stars, planets and the universe" (in the ACE section), where students must rate the statement on a four-point scale from "Not interested" to "Very interested", "School science is rather easy for me to learn"(in the F-sections), which is rated from "Disagree" to "Agree" and "Visited a science centre or science museum" (H-section) to be rated from "Never" to "Often".

Four dimensions of relevance

"Relevance" is the key word in the ROSE-study. Most dictionaries will tell you that the definition of something being relevant involves being *valuable and useful to people in their lives and work.* However, you have to add the questions "Relevant to whom?" and "Relevant in which contexts?" Both questions are central within the ROSE-framework. The objective of ROSE is thus to investigate *in which sense and in which contexts, science, technology and science education are perceived as valuable and useful to the learners (students) in their lives and work.*

In this article four dimensions of *relevance of science in school* are investigated by analysing student responses from the Japanese, English and Danish samples. The question of students' attitudes towards science is thus for the present purpose narrowed down to being a matter of *how and to what extent science as it is taught in schools might be valuable and useful.* The question is attempted answered by analysing 15-year olds' own expressions on these matters in the ROSE-questionnaire.

These four analytical dimensions are defined by items in the F-, G- and ACE-sections as follows:

Dimension 1: The 'everyday life' dimension
To what extent is school science valuable and useful to the students in their current everyday life outside school? Five items from the F-section are taken to define this analytic dimension. The statements of these items are presented in table 1. Notice that no specific field (e.g. physics, geosciences, biochemistry…) within science is mentioned in any statements among the F-items. The assumption is that students implicitly will associate the statement with the science-related subjects they are being taught at the time of the filling in of the ROSE-questionnaire.

Dimension 2: The 'future and career' dimension
To what extent is school science valuable and useful to students in terms of preparing for a future career within the field of science and technology and for creating a desire to make a career within this field? The respondents' expressions of agreement to the statements shown in table 2 will be taken as a measure of this dimension.

Dimension 3: The 'science, technology and society' dimension
School science might also be perceived as relevant by students in the sense that they recognize science and technology as important for the development of society and for improving living conditions for human beings. Five items from the G-section constitute this dimension of relevance of school science and are presented in table 3.

Dimension 4: The 'science class content' dimension
It is known from earlier studies that the subject content taught in science classes is of crucial importance concerning the relevance of the teaching situation as seen from the learners' perspectives. The ROSE-questionnaire contains 108 items of the type "I would like to learn about…" followed by a science-related topic such as "Light around us that we cannot see", "Cloning of animals" and "Epidemics, diseases causing large

Item	Statement	Mean			Mean difference		Country
		Girls	Boys	All	G-B		
F04	School science has opened my eyes to new and exciting jobs	2.05	2.39	2.22	-0.34	Sig.	Japan
		2.00	2.29	2.14	-0.29	Sig.	England
		1.81	2.18	1.99	-0.37	Sig.	Denmark
F08	I think that the science I learn at school will improve my career chances	2.13	2.51	2.33	-0.38	Sig.	Japan
		2.73	2.99	2.85	-0.26	Sig.	England
		2.06	2.29	2.17	-0.23	Sig.	Denmark
F14	I would like to become a scientist	1.29	1.82	1.56	-0.53	Sig.	Japan
		1.54	1.88	1.70	-0.34	Sig.	England
		1.39	1.75	1.56	-0.36	Sig.	Denmark
F15	I would like to have as much science as possible at school	1.75	2.18	1.97	-0.43	Sig.	Japan
		1.76	2.09	1.92	-0.33	Sig.	England
		1.62	1.90	1.75	-0.28	Sig.	Denmark
F16	I would like to get a job in technology	1.35	1.99	1.68	-0.64	Sig.	Japan
		1.66	2.46	2.04	-0.80	Sig.	England
		1.46	2.42	1.92	-0.96	Sig.	Denmark

▲ **Table 2:** Student mean scores and gender differences for the five items defining the analytical dimension "Future and career"

Item	Statement	Mean			Mean difference		Country
		Girls	Boys	All	G-B		
G01	Science and technology are important for society	2.96	3.21	3.09	-0.25	Sig.	Japan
		2.90	3.09	2.99	-0.19	Sig.	England
		3.03	3.17	3.10	-0.14		Denmark
G02	Science and technology will find cures to diseases such as HIV/AIDS, cancer, etc.	3.23	3.22	3.23	0.01		Japan
		3.40	3.19	3.30	0.21	Sig.	England
		3.24	3.11	3.18	0.13		Denmark
G03	Thanks to science and technology, there will be greater opportunities for future	2.79	2.92	2.86	-0.13		Japan
	generations	3.22	3.21	3.22	0.01		England
		2.91	3.00	2.96	-0.09		Denmark
G04	Science and technology make our lives healthier, easier and more comfortable	2.63	2.78	2.71	-0.15		Japan
		3.06	3.07	3.07	-0.01		England
		2.67	2.86	2.76	-0.19	Sig.	Denmark
G05	A country needs science and technology to become developed	2.78	2.95	2.87	-0.17	Sig.	Japan
		2.80	2.94	2.87	-0.14	Sig.	England
		3.05	3.07	3.07	-0.02		Denmark

▲ **Table 3:** Student mean scores and gender differences for five items defining the analytical dimension "Science, technology and society".

loss of life". An analysis of the responses to these 108 items will show which topics would make science classes more relevant to the students, with regard to the content being taught.

Results

In order to reduce the complexity of the data, a coding of the responses with the assumption of a linear scale is adopted in the present analysis of student responses. The mean score of a particular item is thus calculated by assigning scores (1, 2, 3, 4) to responses in the four categories ranging from "Disagree" to "Agree" (in the case of e.g. F- and G-items). This representation of data simplifies the initial analysis and leads to some general conclusions concerning the four above-mentioned relevance dimensions.

In tables 1-3 the means for the item groups defining the relevance dimensions 1-3 are calculated for the respondents from the Japanese, English and Danish national samples. The means are shown for girls, boys and for all respondents in the national samples. The sample sizes are 560, 1266 and 538 for Japan, England and Denmark. In addition the gender difference defined as Mean(girls)-Mean(boys) is shown as well as a note of whether this difference is statistically significant ('Sig.') for the specific samples size as indicated by a two sample *t* test with a 95 % confidence interval. With the applied linear scale a mean score of 2.5 for a particular item is to be considered neutral and indicating neither noteworthy positive nor negative mean attitude towards the corresponding statement.

Table 1 shows that the perceived relevance in the everyday perspective is generally below the neutral line for the Danish students and with no significant gender differences on any items. For the Japanese and English samples, two and three items respectively, score above 2.5, while two items score below. The item F07 scores relatively highly for all three samples, while the item F09 scores low. The latter item reflects a key element in many science curricula: the aim to foster the critical ability. The Japanese sample features significant gender differences for four items. The overall conclusion is that science classes in Japan and England are not overwhelmingly relevant to students seen from the 'everyday life' perspective, while they seem to be of even less relevance in Denmark.

The results from responses concerning the "Future and career" dimension are thought-provoking. Firstly, the mean values for the national samples are significantly below 2.5 for all items with F08 in England as the only exception. Somehow British schools seem to be good at communicating the message to the pupils that science can improve career chances, while this is apparently far from the case in Denmark and Japan; especially concerning the girls. Secondly they are strong gender differences for all items in all three samples, indicating that the future and career aspect of science classes is much weaker for

F16. I would like to get a job in technology				
	Disagree	>>>>		Agree
Girls				
> Japan	75	19	3	3
> England	56	27	13	4
> Denmark	67	24	7	3
Boys				
> Japan	43	26	19	12
> England	26	24	28	21
> Denmark	24	29	28	19

▲ **Table 4:** Frequency table (percentages) showing student responses to the statement "I would like to get a job in technology"

Item	Statement	Mean			Mean difference	
		Girls	Boys	All	G-B	
C13	Why we dream while we are sleeping, and what the dreams may mean	3.34	2.34	2.85	1.00	Sig.
A40	How to exercise to keep the body fit and strong	3.24	2.74	2.99	0.50	Sig.
E11	What we know about HIV/AIDS and how to control it	3.20	2.58	2.90	0.62	Sig.
E13	How different narcotics might affect the body	3.18	2.65	2.93	0.53	Sig.
E09	Sexually transmitted diseases and how to be protected against them	3.16	2.66	2.91	0.50	Sig.
E12	How alcohol and tobacco might affect the body	3.14	2.68	2.92	0.46	Sig.
E08	Cancer, what we know and how we can treat it	3.12	2.60	2.87	0.52	Sig.
E10	How to perform first-aid and use basic medical equipment	3.12	2.70	2.92	0.42	Sig.
A37	What to eat to keep healthy and fit	3.11	2.35	2.73	0.76	Sig.
A38	Eating disorders like anorexia or bulimia	3.03	1.81	2.43	1.22	Sig.

▲ **Table 5a:** Mean scores for the 10 highest scoring items among Danish girls in the ACE-section: "What I would like to learn about".

the girls. Danish boys and girls score lower on all items compared with the English and Japanese students, with the item (F16) concerning 'getting a job in technology' as the only exception (and F14 for the girls). The distribution of responses for F16 is shown in table 4 in which the large gender difference is even more striking. Roughly 60-75% of the girls completely reject the thought of making a career in technology. Only in England does the percentage of girls expressing any wish to work in this field exceed 10%. With respect to the boys, Japan seems to have a particular problem, since close to 70% generally disagree with the statement. The conclusion from this analysis is that with respect to the 'future and career' perspective, science classes in the three countries seem to be of little value in particular to girls and to the Danish boys.

In table 3 the mean values for the five items of the 'Science, technology and society' dimension are listed. The first thing to notice is that mean values in general are well above 2.5 indicating an overall large degree of acknowledgement of the importance of science and technology in creating better living conditions in the future and in general in enabling the development of societies. There is an especially strong belief in the potential for finding methods for curing diseases (G02), in particular among girls. Apart from this item, girls generally score lower on these items than boys, though the differences are far from the level featured in table 2.

Finally, table 5a and 5b give an example of how the value of science lessons may differ for groupings of students depending on the subject content taught in a specific class. The table shows the ten highest scoring items, for Danish girls and boys respectively, among the 108 ACE-items with the heading "What I would like to learn about". It is worth pointing out that girls' mean scores in table 5a are very high – indicating a strong agreement between the girls that these subjects are interesting. Also, the very large gender differences for these 10 items should be pointed out. Girls' interests seem to be focused on health, medicine, body and themes related to themselves. The corresponding table for the boys features mean values that are somewhat lower than observed for the girls and gender differences which are more varied. For seven of the items, the boys' mean scores are significantly higher than the girls' score, but when it comes to learning about life outside the earth and feeling weightless, no difference can be shown. There is even one item ("How to exercise to keep fit and strong") on the boys' top 10 list, for which the girls' score is higher. The boys' responses indicate a wish to learn about the dramatic and violent aspects of physics and chemistry and about how technology works. Finally it should be mentioned that Jenkins (Jenkins & Nelson, 2005) has published a range of analyses based on the English ROSE-data and includes the English "Top-10 lists" corresponding to table 5a and 5b. There is a striking resemblance between the two sets of lists with eight of ten possible overlapping items for the girls and six of ten overlapping items for the boys. More results from the national Japanese ROSE-study can be found in (Ogawa, 2004), whereas a range of analyses of Danish results is available on the homepage for the Danish ROSE-project: www.dpu.dk/rose.

Discussion

The results of the analysis presented in this article are very well summarized by the title of the recent paper by the English ROSE-team (Jenkins & Nelson, 2005) "Important but not for me: students' attitudes towards secondary school science in England". We have shown that English, Japanese and Danish 15-years olds find school science only moderately relevant from an everyday perspective and of little value from a 'future and career' point of view. The last conclusion is especially pronounced for girls in all three countries and for Japanese boys as well. On the other hand, there is a clear acknowledgement of the benefits of science and technology for society and for the individual in terms of development, finding cures for diseases and creating better living conditions in general.

Summing up, there seems to be an understanding among young people of the fact that knowledge- and technology-based societies need more scientists, but at the same time a lack of will and motivation to devote one's own working life to support this development. In (Schreiner & Sjøberg, 2005) a preliminary international comparative analysis including all ROSE-countries has been presented. It is clear from this work that (generally speaking) northern European countries and Japan, followed by Eastern and Southern European countries tend to score lowest on the three 'relevance' dimensions presented in tables 1-3. At the other end of the scale, African countries (from mainly south of the Sahara) score very high and are followed by the participating Asian countries with only somewhat lower scores.

Item	Statement	Mean			Mean difference	
		Girls	Boys	All	G-B	
A30	How the atom bomb functions	2.28	3.05	2.67	-0,77	Sig.
C07	How computers work	2.17	3.00	2.58	-0,83	Sig.
A31	Explosive chemicals	1.94	2.87	2.40	-0,93	Sig.
A32	Biological and chemical weapons and what they do to the human body	2.28	2.87	2.58	-0,59	Sig.
A34	How it feels to be weightless in space	2.74	2.78	2.76	-0,04	
C08	The possibility of life outside earth	2.87	2.78	2.83	0,09	
C04	How cassette tapes, CDs and DVDs store and play sound and music	2.00	2.77	2.38	-0,77	Sig.
A40	How to exercise to keep the body fit and strong	3.24	2.74	2.99	0,50	Sig.
C03	The use of lasers for technical purposes (CD-players, bar-code readers, etc.)	1.84	2.72	2.27	-0,88	Sig.
E41	Very recent inventions and discoveries in science and technology	2.09	2.71	2.40	-0,62	Sig.

▲ **Table 5b:** Mean scores for the 10 highest scoring items among Danish boys in the ACE-section:"What I would like to learn about".

It is important to develop a better understanding of the reasons for the "Science is important but not for me"-attitude in order to secure a high level of scientific literacy in the population and to increase recruitment to science and technology studies. An understanding of the (post-)modern society, of the youth cultures created by this society and of the latent attitudes towards science within these cultures is a prerequisite in order to make the changes necessary in school science. The ROSE-study will produce the evidence-based characteristics of these attitudes, which, combined with proper sociological theories, will hopefully provide us with the necessary qualitative understanding. ■

About the Author

With a Ph.d. in physics from the Niels Bohr Institute, Henrik Busch moved in 1998 from the field of research in nanoscience in to research in science education. He is currently an associate professor at The Danish University of Education in Copenhagen. Lately has has co-authored the strategy plan for science education on behalf of the Danish Ministry of Education, he is chief-editor of the first Danish research-based journal of mathematics- and science education and he is the leader of the Danish ROSE-project.

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SkyWatch: introducing european youth to the world of Astronomy

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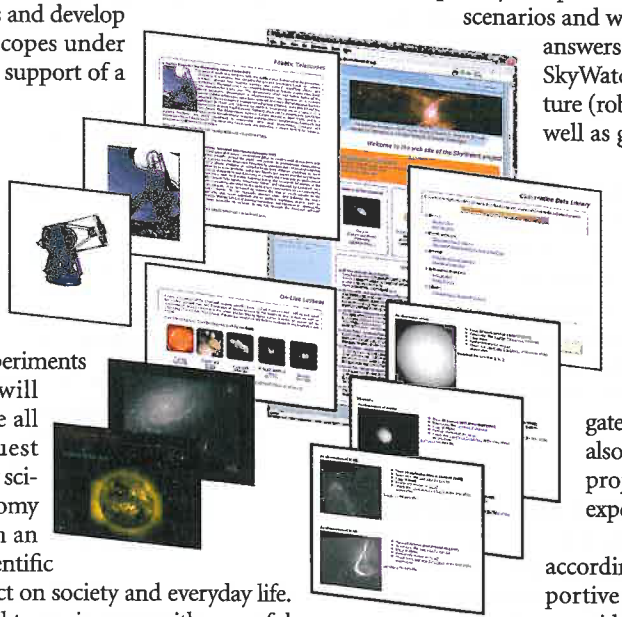
The aim of the SkyWatch Project is to create a virtual community of young prospective researchers who have been involved in a series of science projects. The Project provides students with the possibility to use real-time robotic telescopes to perform observations, analyze data and suggest solutions and answers to selected research topics using a web-based learning environment. The Project's activities will be spread through a European Science Contest, a series of popular science distance-learning courses, and the promotion of concepts and ideas of multidisciplinary science. Students are encouraged to organize teams and develop activities using the robotic telescopes under the guidance and the continuous support of a team of experts in the field.

Project's Description

The Project [1] uses an innovative approach to promote increased public awareness of scientific and research culture. Combining schools, research centres and science thematic parks, users will be able to participate in hands on experiments and research. This approach will engage groups of young people all over Europe in a scientific quest through a set of multidisciplinary scientific scenarios related to astronomy and astrophysics that gives them an opportunity to participate in scientific research and to evaluate its impact on society and everyday life. SkyWatch is an initiative designed to equip users with powerful real-scale research tools become researchers, leading them to become the seekers and finally the leaders of the scientific quest.



Students will also see the benefits of European co-operation in research through SkyWatch, as the tools that they will use are the result of trans-national co-operation. SkyWatch activities will lead to the creation of an education and 'public awareness of science' network. Over 70 schools from 28 European Countries and 30 universities and science centres are expected to participate in this network.

The SkyWatch Web Portal

The SkyWatch portal is the place where contest participants can find general information on the project (competition guides, evaluation criteria, description of the selection procedure), all the necessary research results, and support material. The portal also has an up-load facility for contest participants to submit their projects. Discussion forums and on-line support sessions help the participants to exchange their ideas and views and to obtain feedback from the SkyWatch team. The contest participants will receive a regular electronic newsletter throughout the duration of the Project to keep them updated on the activities in all the science projects. Interesting news items will be posted on the SkyWatch portal The SkyWatch portal will also provide an online campus with information and tools such as multi-lingual repositories of educational material as well as communication and collaboration tools.

Examples of resources available on the portal include projects, lesson plans, educational material for teachers, and images. As each resource comes into existence, its components are encapsulated in XML and are further annotated with the appropriate metadata protocol, to permit queries for future use.

The SkyWatch Contest

The first phase of the Science Contest is the selection of the scientific topics by the participants. They are then asked to create scenarios and well-defined small projects to search for answers to these questions. The facilities of the SkyWatch Project, both in terms of infrastructure (robotic telescopes, portal and databases) as well as guidance and support by the scientific team of experts that the SkyWatch partnership will provide in replying to questions. In particular, for each topic that the SkyWatch team has selected, a resource guide exists that provides background information designed to engage students, groups and individuals in learning about the specific topics and designing their own projects to investigate further and learn more. Participants can also submit the preliminary results of their project to have feedback and guidance by experts.

Different contests are organised according to the ages of the participants. Supportive material has been developed, such as contest guides, evaluation guidelines and rules of participation and forms the contest package delivered to all participants (groups and individuals). Contest can be organised either in formal learning environments (schools or universities in the framework of their normal curriculum) or in informal learning environments (science parks, museums and centres, home).

An initial selection procedure will be established that will lead to the creation of a pool of 30 projects suitable for presentation during the European Science Week 2005 and for candidacy for awards of the best projects. This evaluation/selection procedure will be followed independently for each of the two groups (students and the wider public) of contestants, and in the case of students, according to age groups.

[1] The Sky Watch project is co-financed by the European Community, within the framework of Science and Society, FP6-2003-7-013609. The Sky Watch consortium is composed by the following partners: Q-PLAN (GR), EDEN - Open Classroom (UK), Astrophysics Research Institute (UK), European Physical Society (FR), Ellinogermaniki Agogi (GR), Stockholm University (SE), SCIENCE PROJECTS (UK) and University of Duisburg – Essen (DE).

Scenarios for science projects

The scenarios for the contests vary significantly in order to cover the different needs and interests of the different groups of participants. The scenarios address science topics from multiple viewpoints and integrate with other fields of science. These scenarios are one of the basic vehicles for the promotion and the dissemination of science and technology to the young participants. The scenarios are categorized in two main groups. The first group includes scenarios for the specific educational purposes of the school and/or university curriculum (scenarios to be used in formal learning settings). The second group includes more open scenarios that are designed for the wider public (e.g. the visitors of a science centre). All the projects will be presented and assessed by the Project's scientific committee. Evaluation methodology and the selection procedure have been agreed and adopted.

Expected impact – future plans

School students, university students, educational authorities, teachers, and the general public are expected to participate actively in the Project. Younger school students will learn more about research through hands-on experiments. The "Science Contests" will constitute the driving theme and concept to stimulate the interest of young people in science through taking part in an experience that involves learning, competition and entertainment and highlights the excitement of the scientific quest. Through its activities the Project aims to raise the European young people's interest and awareness of science and technology as well as to create and support virtual learning communities of young people, educators and researchers. In the long run, the Project hopes to establish an annual European Award Competition in science and technology, especially in astronomy and physics, as well as to stage an Annual International Exhibition. ■

Synchrotron light in the Middle East

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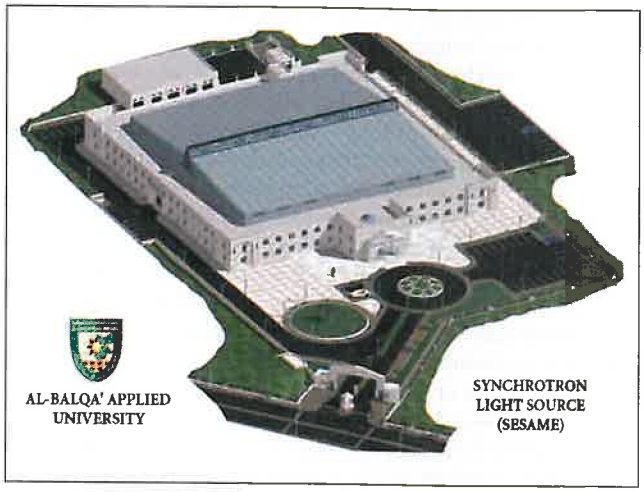
Middle East College of Information Technology, Muscat, Sultanate of Oman.

The region of Middle East has joined the world of synchrotrons, comprising about fifty synchrotrons located in twenty-three countries. The Middle East synchrotron is known by the epical acronym SESAME: *Synchrotron-light for Experimental Science and Applications in the Middle East.* Here, we recall the magic word open sesame from the *Arabian Nights Entertainments* meaning, achieving what is normally unattainable! SESAME is hosted by the Al-Balqa' Applied University, 30km northwest of the Capital Amman. The SESAME Project was born in 1997, when Germany decided to replace its, fully functioning BESSY-I synchrotron in Berlin by a more powerful facility. Germany gifted BESSY-I to the Middle East, the only region other than Africa without a synchrotron.

The 800MeV BESSY-I was shipped to Jordan in June 2002, where it is being upgraded. The machine design is based on a 2.5GeV, 3rd generation light source. On 6 January 2003, King Abdullah of Jordan laid the cornerstone for the Middle East's first synchrotron. In April 2004 SESAME was formally established as an autonomous intergovernmental organization following the model of CERN, the



European Laboratory for Particle Physics. Like CERN, SESAME is under the valuable political umbrella of UNESCO (United Nations Educational, Scientific and Cultural Organization) and is expected to promote science and foster international cooperation. Any country can join SESAME by sending a letter (from the head of state or foreign minister) to the Director-General of UNESCO. Present *members* are Bahrain, Egypt, Iran, Israel, Jordan, Pakistan, Palestine and Turkey. Some countries are participating as *observers:* Greece, Germany, Italy, Japan, USA, UK, Kuwait and Libya. Several other countries are expected to join.

The research programmes, including, structural molecular biology, molecular environmental science, surface and interface science, micro-electromechanical devices, X-ray imaging, archaeological microanalysis, materials characterization, and medical applications, are expected to commence in 2009 (www.sesame.org.jo). It is an excellent opportunity for the countries of the Middle East (and Africa) to join SESAME the first international science centre in the region. SESAME operates like a mini-CERN in the Middle East, promoting science and fostering international cooperation. With the success of SESAME, it is time to start planning for an African synchrotron. ■

ITER is to go ahead in Europe – what happens now?

Jo Lister,
Centre de Recherches en Physique des Plasmas, Ecole Polytechnique Fédérale de Lausanne, Switzerland

After protracted negociations and an 18 month stand-off between Europe and Japan, agreement was finally reached by the ITER Partners at Moscow on June 28th, establishing Cadarache (France) as the ITER site. Several actions have been taken to organising the different implementation levels which this large project requires. « Negociators Standing Sub-Group » meetings will take place once a month until the end of 2005 and the Partners will produce the draft of an International Agreement. Meanwhile a General Director will be appointed. Attributing the in-kind

construction packages among the Partners will also have to be decided. At the European level, the organisation of a "European Legal Entity" will be worked out on about the same time scale and the agreement of the Council of Ministers will be sought. This European organisation will be responsible for the European contracts, including site preparation, collaborating with the "French Legal Entity". This will be an independent agency in charge of coordinating the numerous French organisations involved and interfacing with the European administration. A formal public debate will take place in France in the autumn of 2005 to evaluate the reactions of the French population to the project, even though there was already very strong local and regional support for the Cadarache candidature.

The first task of the ITER General Director will be to review the existing detailed design and to produce a « site specific » design, essential for the licensing procedure. The most urgent tasks are to build up the core team and to prepare the technical specifications for the longest lead-time hardware, especially the large quantity of superconducting material needed for the ITER coils. If all goes well, the first bids could be launched by the end of 2006, the licensing procedure could be completed by the end of 2007 and actual work on site could start early in 2008.

Parallel to this preparation for the ITER project itself, discussions have already started between EU and Japan to work out the details of the « broader approach », wich is an essential part of the agreement signed on June 28th. This broader approach includes studies and provisons for installations in Japan financed in common. These are primarily a neutron test source for qualifying reactor materials needed for DEMO, the demonstration reactor after ITER, the construction of a large non-nuclear superconduting tokamak (JT60SU) in support of ITER, a modelling centre for fusion science and finally a coordination centre for reactor technology. Clear choices have to be agreed between Japan and EU with the aim of contributing to fast development of fusion energy. The size of this "broader approach" is the price paid for breacking the deadlock over the site of ITER itself.

In both the EU and Japan, the impact on the present scientific research programme of both the construction of ITER and the financing of the "broader approach" will take time to analyse. ■

Council participants listen the presentation.

Council 2005

Exceptionally, the 2005 EPS Council Meeting in Bern (CH) was held on 6 and 7 July, rather than the last weekend in March. This was motivated by the desire to co-locate the Council meeting with the EPS General Conference – EPS13 "Beyond Einstein: Physics for the 21st Century" also held in Bern from 11-15 July. The EPS Council Meeting in 2006 will be held on March 24 and 25 in Mulhouse at the EPS Secretariat.

Martin Huber in his President's Report set the tone for the meeting. Reminding the participants that the EPS, while focussing its actions on physics, actually has a broader geographical influence within the EU. The EPS is playing an active role in shaping science policy in Europe, particularly with regards to creation of the European Science Council. The ERC is part of the Framework Programme 7 and in order to make the ERC an effective body to promote the interests of science in Europe, the EPS and many other learned societies including the European Life Sciences Forum have come together in an informal group known as the Initiative for Science in Europe. The ISE has argued that the ERC is an essential tool in developing the knowledge-based society in Europe, and must be used to finance curiosity driven frontier research. The ERC will also be a motor in driving national research efforts, hopefully leading to greater cooperation among national science councils. The ERC will cover all fields of research, including humanities, social and natural sciences. The most important criterion is scientific excellence, based on a peer review of the research projects. A significant budget, coming from new sources and not redirected from existing research programmes is also necessary, and the indicated amount is between € 1.5 and 2 billion. The ISE has published a letter in Science (August 6, 2004) and made an appeal to the EU research ministers in June 2005 in support of the ERC.

The EPS has also been active in supporting the proposal 'fundamental physics in space' that is part of the European Space Agency programme, Cosmic Vision 2015-2025. A position paper has been published, and distributed to ESA members. The purpose of the position paper is to encourage physicists to make use of the advantages of performing experiments in space, and urges governments to support these experiments.

Through the efforts of the EPS under the leadership of M. Ducloy, 2005 was declared the World Year of Physics by the international physics community, including the EPS, IUPAP, FELASOFI, the APS, and AAPPS with the support of UNESCO. The UN declared 2005 the International Year of Physics. Thousands of educational and 'public understanding of physics' initiatives have been planned in 2005. The EPS, and 23 other partners in Europe, has received EU funding for WYP2005 activities in Europe. The EPS has notably organised the WYP2005 Kick-off Conference (January 2005, Paris) and EPS 13 as part of its contributions to activities during the year.

The new EPS Constitution, voted in 2004 and applicable in 2005 has opened the possibility of more than one physics-related society per country. The Executive Committee has begun examining which societies should be approached, and has begun by identifying those which are particularly strong in physics education. Also, according to the new Constitution, members of the Executive Committee serve 2 year terms, so no elections were organised this year. The current members of the Executive Committee are: M. Allegrini (Treasurer), G. Delgado-Barrio, B. Feuerbacher (Vice-secretary), P. Hoyer, H. Kelder, M. Kolwas, A.M. Levy, P. Melville (Secretary), and Z. Rudzikas.

O. Poulsen elected as President-elect was confirmed as President of the EPS, and M.C.E. Huber was confirmed as Vice-president.

The EPS has also concentrated on improving its visibility through its publications. As reported in EPN 35-4, C. Sébenne has assumed overall editorial responsibility for Europhysics News. He replaces G. Morrison, who in his 6 year term as Editor made important contributions to improving the layout, timeliness, and quality of the scientific feature articles. C. Sébenne will build on these achievements, and bring more news of interest to EPN's readers. G. Morrison will continue as the Science Editor, responsible for the feature articles.

The Editorial Office of Europhysics Letters moved to the EPS Secretariat, with 2004 as the first full year of activity. Plans are underway to make EPL one of the world's leading letters journals.

Innovative features of this year's Council meeting included a seminar on "How national societies could increase their membership" and a seminar on "Physics education".

In the seminar on "How national societies could increase their membership", presentations were made by Z. Rudzikas (LT), K. Hamalainen (FI), and R. Sauerbrey (D), representing the viewpoints of small, medium and large societies respectively.

In Lithuania, although newly admitted to the EU, salary levels for researchers remain low as compared with Western Europe. Any increase in membership of the Lithuanian Physical Society will increase its membership fees to the EPS, and this is a problem. Moreover, the membership fee to join the EPS represents a substantial amount for Lithuanian physicists. Nonetheless, membership in the EPS at both the national and individual level is seen as advantageous for contacts and prestige. In order to increase its membership, small societies in similar situations need to take advantage of the provisions in the EPS Constitution that allow for the negotiation of lower membership fees.

The Finnish Physical Society has approximately 1,100 members, mostly academic physicists. This does not include physics teachers, who have their own society. There is not much room for growth of the FPS as most academic physicists are already members. The main activity that is of interest to its members is the annual meeting, which provides an opportunity to meet colleagues from around Finland. The problem is to ensure that young physicists join. To attract young physicists, it is necessary to give them positions of responsibility, and make them part of the community.

The DPG is the world's largest physical society with over 50,000 members representing about half of all physicists in Germany. To achieve this result, the DPG made a communications plan using professional guidance, culminating in "Jahre der Physik" in 2000. Concentrating on young physicists, the DPG offers free membership to physics students. To promote physics studies, book prizes are organised at the high school level to identify promising students who are also given free membership. All young members are eligible for travel grants. Other activities include annual regional physics festivals, public lectures, an annual conference (the largest in Europe), and the publication of the Physik Journal.

In the seminar on "Physics education", presentations were made by H. Busch on the ROSE (Relevance of Science Education) project, H. Ferndinande on EUPEN and the Stakeholders Tune Physics Studies (STEP) project, C. Madsen on "Some thought on Physics Education in Europe" and J. Holbek on Higher Order Thinking (HOT) Physics.

The Relevance of Science Education Project (ROSE), under the direction of S. Sjoberg, is studying the interest, relevance and attitudes of students around the age of 15 in 40 countries to science and technology. The purpose is to develop policy recommendations to be used in formulating science and technology education, and to highlight the importance of science and technology education in society. The method used consists of a series of questions on what students think about science and technology. The summary conclusions show that overall, science and technology are seen to be useful and important, but there is little interest to pursue a career in these fields. The preliminary results of the study show that boys are more interested in science and technology, and that students from developing countries are more interested in following careers in these fields.

The study wants to understand what sociological reasons have led to a decline in interest to follow a career in science and technology. It has identified numerous factors, including loss of orientation and individualization. When applied to a teaching context, this means that students require courses to be personally meaningful. Science and technology curricula do not address the needs of the students. In H. Busch's analysis, they are too general, too theoretical, and do not stimulate curiosity. The website is www.ils.uio.no/forskning/rose/.

EUPEN was an EU funded project which studied the content of physics studies at the university level in 30 countries and in 150 institutions. Based on these findings, it is necessary for the stakeholders (physicists, universities, learned societies) to make proposals to enhance physics education and develop projects to make physics more interesting, increase the number of students, and increase the awareness in the general public of the importance of physics. STEPS will also help to implement the Bologna process and to implement a European Higher Education Area by 2010. The project will bring together 171 institutions in 31 countries.

Thoughts on Physics Education in Europe began with stating that the attitude towards science in the EU is not bad, though it could be better. The main problem is a breakdown in communication between the scientists/educators and the students. We first need to define what we mean by science education, including science literacy. It could mean use of daily appliances (computers, telephones...), understanding health issues, the ability to answer specific questions about science, the ability to participate in discussions about socio-scientific issues, or the ability to use scientific methods and reasoning. Teaching physics needs to teach different types of scientific literacy and not only identify new scientists.

Teaching science is a broad discipline that involves many actors who need to communicate more among themselves. Any teaching

The numerous events organised by the institutions of education and science have been co-ordinated by the 'Forum Einstein 2005 Bern'. The concluding event, a jazz concert in a tent on the 'Einsteinterrasse' was also the scene of the handover of the presidency of EPS.

and outreach programme should have the following basic components: a good narrative and active participation of the learners; it should assume little previous knowledge on the part of the students, use visual supports, and leave the participants with a feeling of accomplishment.

Current teaching methods in science give answers, but do not ask questions, therefore stifling curiosity. Interdisciplinary activities, current real science in teaching, hands-on experience, and the history and philosophy of science need to be incorporated into science teaching.

Higher Order Thinking (HOT) in Physics teaches students how to solve problems. People develop over time, and the ability to resolve complex problems, moving from simple relationships to abstract relationships is usually acquired between the ages of 12 and 18. J. Holbeck, and others who study how to teach physics have tried to break problem-solving abilities into different phases. This is quantified by the number of variables an individual can integrate in solving or analysing a problem. Comparing this to how physics is taught, the conclusion was that the textbooks tend to teach only in terms of complex, abstract thinking, but do not teach the tools required to solve the problems.

The Cognitive Acceleration through Science Education (CASE) uses the HOT concept, and also teaches problem solving, and teaches students techniques ranging from control of variables to modelling. It is a combination of curriculum tasks and teaching methodology. Analysis of the results shows that students who have learned problem-solving techniques do much better in science and technology courses and mathematics. Moreover, they also do better in other subjects such as language studies, and history.

In Denmark, CASE has been adapted to upper secondary schools and teaching materials have been created. At present, 140 teachers have received training in using CASE.

Physics education will be the priority under the presidency of O. Poulsen. The EPS is currently working on its policy, strategy and activities in this area. A first draft will be available at the end of August 2005. Council 2005 not only reviewed the activities of 2004 but also discussed the issues that are of importance to the growth of the EPS and to physics in Europe. ■

Agilent Technologies Europhysics Prize 2005

The 2005 Agilent Technologies Europhysics Prize is awarded to **D. Awschalom, T. Dietl** and **H. Ohno** for pioneering investigations of ferromagnetic semiconductor heterostructures and for developing methods of controlling alignment and coherence of the spin of mobile carriers. This paved the way for the emergence of semiconductor spin electronics.

Modern information technology is based on physical properties of particularly tailored systems of metals and semiconductors. Information processing relies on electrical currents in semiconductor heterostructures, based on III-V semiconductor compounds, and electronic transitions generating photons in these systems provide the basis for the transmission of information. The electronic transport properties of metallic multilayer systems containing magnetically active components are dominated by the spin-dependent scattering of electrons and are employed in combination with information storage systems.

A. Ohno, T. Dietl and D. Awschalom receive their prize from U. Nussbaumer of Agilent Technologies

In order to include the control of the spin degree of freedom of itinerant charge carriers also in semiconductors, new materials in the form of semiconductors exhibiting magnetic order had to be developed and significant advances in this respect were made in recent years. Based on these materials, a new field of spin-dependent electronics, now termed spintronics, emerged with a large impact both in basic and applied physics.

An essential step forward in the development of combining electronic and photonic capabilities of functional III-V semiconductor heterostructures with magnetism was made with the discovery of ferromagnetism in (Ga,Mn)As in Hideo Ohno's laboratory. Although the concentration of the magnetic Mn ions was only at 5%, the reported Curie temperature of 110 K turned out to be amazingly high. Ohno, also one of the pioneers of epitaxial growth of layered structures, continued to search for new functional materials of this type and succeeded in the case of, e.g., (Ga,Mn)Sb and CrSb. Further progress on the materials side was initiated by Tomasz Dietl's prediction of ferromagnetism in specially tailored II-VI semiconductor structures, doped with Mn replacing the II component at the few % level. In a collaborative effort between the groups of T. Dietl in Warsaw and J. Cibert at Grenoble, these predictions were soon confirmed for two-dimensional modulation-doped (Cd,Mn)Te/(Cd,Zn,Mg)Te:N heterostructures and in uniformly doped bulk epilayers of (Zn,Mn)Te:N.

Dietl and collaborators were particularly instrumental in developing the theory of hole-mediated ferromagnetic order in tetrahedrally coordinated semiconductors. They analyzed the importance of experimentally controllable parameters and their work led to the discovery of the above mentioned material systems. In particular it was shown that the use of the technique of modulated doping can also be used for controlling magnetic properties, leading to the electric-field control of ferromagnetism in semiconductors.

Soon a variety of different experiments of the awardees and their collaborators indicated the innovation potential of this type of magnetic semiconductor systems. The groups of David Awschalom and H. Ohno reported the fabrication of light-emitting p-i-n heterostructures of III-V compounds where, in zero magnetic field, spin-polarized holes are injected from the p-type (Ga,Mn)As into a non-magnetic (In,Ga)As quantum well embedded in GaAs. In this and further work by these groups and L. Molenkamp's group at Würzburg, it was demonstrated that

heterostructures of this type can be used to inject spin-polarized holes and electrons. Spin-polarized electrical currents offer many new applications, particularly also in the sector of radiation generation via electronic transitions in corresponding structures, such as quantum-well laser diodes.

Pioneering experimental work of Awschalom and co-workers, based on femtosecond time-resolved optical spectroscopy, provided access to probing the temporal and spatial variations of the spin degrees of freedom in this type of materials. The method of Awschalom proved to be especially adapted to measurements of the lateral drag of spin coherence. Another particularly encouraging result was the demonstration of long spin coherence times in suitable material systems. This observation makes the use of spin dynamics an attractive option for future concepts in quantum computing and quantum information processing.

A large and growing number of scientists have contributed to the rapid development of the field of spintronics in semiconductors. In the wake of the afore-mentioned pioneering work, national and international programs devoted to this type of research were initiated, which reflects not only the interest in the fundamental aspects of this area of physics but also the expectations and hopes for future technological applications. The outstanding and leading role of the awardees is fully recognized by the community and reflected in important national awards and numerous invitations as plenary speakers to international conferences. The selection committee is therefore convinced that the award of the Agilent Technologies Europhysics Prize 2005 to David Awschalom, Tomasz Dietl and Hideo Ohno is well deserved. ■

Public Understanding of Physics Prize 2005

The European Physical Society's Public Understanding of Physics Prize 2005 is awarded to Martial Ducloy for his outstanding contributions to science and society, in particular the initiation of the World Year of Physics.

Martial's nomination was widely supported by the European physics community, including the physical societies in Belgium, Bulgaria, the Czech Republic, the Russian Federation, Switzerland, Portugal, the Netherlands and the United Kingdom through the Institute of Physics.

Martin Huber and Martial Ducloy, laureate of the 2005 PUP prize at the Physics Poster Competition.

He is well know to all of us and has made valuable contributions as a working physicist in the field of quantum electronics and lasers. His research and organisational abilities are also well recognised by his university in Villetaneuse, Paris Treize, where he has held successive positions as the Vice-president for research and the Vice-president for international relations.

He joined the EPS shortly after its creation in 1968, and has been a fervent supporter of its activities. He was chairman of the EPS Quantum Electronics Division from 1994 to 1998, and was instrumental in the creation of the EPS conference services department, and in the organisation of the CLEO/Europe – EQEC conference series. He became EPS president - elect in 2000, and served as President in 2001 and 2002.

In 2000, at the 3rd World Congress of Physical Societies in Berlin, Martial proposed to more than 30 societies present that 2005 be declared the World Year of Physics. This initiative was inspired by the Jahres der Physik which generated enormous enthusiasm for physics in Germany during the year 2000, and by the World Year of Mathematics. Learning from our German colleagues, and those in mathematics, Martial worked tirelessly with the help of notably Chris Rossel and Martin Huber to obtain widespread international support. IUPAP endorsed the World Year of Physics in 2001, UNESCO added its support in 2004, culminating with the declaration of 2005 as the International Year of Physics by the United Nations General Assembly.

Since then, thousands of projects from around the world have been held celebrating 2005 as the World Year of Physics. The European Commission recognised the importance of this initiative with a 2.1 million Euro contract to finance hundreds of projects in Europe during 2005.

We all hope that the outcome of 2005 will be a better understanding by the general public of the importance of physics in their lives, more dialogue between the physics community and policy makers to address such future challenges as renewable energy, global warming, and medicine, and most importantly, renewed interest in the young generation to follow careers in physics.

WYP2005 can already be proclaimed a success, and we owe our thanks to Martial Ducloy for his efforts and contributions to this initiative. ■

Gero Thomas medal for services to EPS

John Lewis, who has always identified himself as a schoolmaster, spent virtually all his career at Malvern College, where he had previously been to school before studying physics and mathematics at Cambridge and where he was Head of the Science Department from 1955 until his retirement in 1983. During this time his was active, not just in teaching pre-university physics, but also in developing physics teaching nationally, for example playing a leading role in the Nuffield advanced physics project. As a celebrated educationalist, John has also travelled around the world studying and advising on physics education. Anyone who has heard him talk on physics education or seen him give demonstrations will realise what a splendid teacher he was. In retirement John has been no less active, first becoming the Institute of Physics' Vice-

President for Education and then its Honorary Treasurer. At first he protested that he knew nothing about money, but was told that what was important was that he was good at asking questions. And what a fine Treasurer he was.

On the basis of this and his reputation for asking questions, John Lewis was nominated as EPS Treasurer in 1994 and served for five years until 1999. He insisted that he was not prepared to serve unless the accounts were properly audited, which they had not been until then as it was not a requirement under Swiss law. When it took place, the audit revealed that EPS had a very heavy deficit of which EPS Council was on the whole unaware. Revealing this gave John a considerable and well-earned reputation. The decision was then taken to move the headquarters from Geneva over the border to Mulhouse, where the overheads were substantially less. The net result was that by the time John handed over to his successor the deficit had become a surplus. There is no doubt that EPS owes John a substantial debt of gratitude for putting EPS on a proper financial footing and for seeing EPS through the move from Geneva to Mulhouse.

John will also be remembered for the Malvern Seminar – The International Seminar on Physics Education which he organized at Malvern College in 1999. Taking advantage of EPS-11 in London, this was attended by most of the presidents of physical societies in Europe. This proved a most stimulating event and opportunity to share experience of physics teaching across Europe. One consequence of the seminar was the decision to set up the EPS Education Division with both university and pre-university sections. John also represented EPS on the committee organizing Physics on Stage at CERN in 2000. This has proved a tremendous success and has gone from strength to strength.

John Lewis has provided great service to EPS, which would not be the same today without his efforts. He is a very fitting recipient of the Gero Thomas medal. ■

2005 Prizes of the High Energy and Particle Physics Division of the EPS

The 2005 European Physics Society High Energy and Particle Physics Prize is awarded jointly to:

- **Heinrich Wahl**, for his outstanding leadership of challenging experiments on CP Violation, and to

- The **NA 31 Collaboration**, which showed for the first time Direct CP Violation in the decays of neutral K mesons.

The 2005 EPS-HEPP Young Physicist Prize is awarded to:

- **Mathieu de Naurois**, for his new ideas and decisive contributions in the CELESTE and HESS experiments. His new original method to analyse Cerenkov images of atmospheric showers enabled many new results in HESS and the detection of new sources near the galactic centre. "

The 2005 EPS-HEPP Gribov Medal is awarded to:

- **Matias Zaldarriaga**, for his important theoretical contributions to Cosmology, with impact also on the theories of fundamental interactions. Among others for:
a. developing an efficient method for calculating the observed CMB fluctuations in a given cosmological model. This has greatly facilitated imposing constraints on cosmological models and is widely used.
b. Realizing the importance of polarization in the CMB and the possibility to measure it.
c. Pointing out the importance of the effect of gravitational lensing by local matter on the CMB background."

The 2005 Outreach Prize is awarded jointly to:

- **Dave Barney**, for promoting the fascination of particle physics to the public, in parallel to his research work in the CMS collaboration at CERN. His impressive and successful efforts are concentrated around the CMS experiment, but also reaching far beyond his own experiment.

- **Peter Kalmus**, for his long-standing and major personal involvement in particle physics outreach. In the last years, he has given talks for schools and the public to a total audience of some 24,000 in countries from the UK, Ireland and France to South Africa, Singapore and India. "

EPS conference activities

In 1999, the EPS established a Conference Services department at the Secretariat in Mulhouse. The main reasons for this decision were to offer concrete services to EPS Divisions and Groups through the organisation of their conferences, seminars and workshops; to increase the visibility of the EPS to the global physics community with a strong presence of EPS staff and expertise at conferences; to create an identity for conferences organised by EPS Divisions and Groups; and to develop expertise and centralise know-how, conference procedures, mailing lists, etc. The Conference Services department employs 2 full-time staff, and uses other central services such as information technology, graphic design, web hosting, management and accounting.

Since its creation, the department has been directly involved in 12 conferences, and provided partial services to many others. The EPS can offer a full range of services for conference organisers including brochures, websites, on-line paper submission and refereeing, preparation of programmes and abstracts, both in electronic and paper versions, on-line

CLEO®/Europe – EQEC 2005: A. Zeilinger...

and on-site registration and payment, etc. This frees up the organisers from the Divisions and Groups and allows them to concentrate on the scientific programme of the conference.

In 2004-2005, the EPS has organised the 1st EPS QEOD Europhoton Conference (Lausanne, July 2004), The WYP 2005 Kick-off Conference (Paris, January 2005), CLEO/Europe-EQEC (Munich, June 2005), EPEC1 (Bad Honnef, July 2005), and EPS13 (Bern, July 2005).

Each of the conferences in 2005 was very distinct. The WYP 2005 Kick-off Conference was organised at the UNESCO headquarters as part of the EPS activities for the World Year of Physics. Over 1,000 students attended from over 40 countries to hear about the role that physics plays in society and in future challenges.

CLEO/Europe-EQEC 2005 is part of a series of conferences that is co-organised by the EPS QEOD and two American partners, the OSA and IEEE/LEOS. The conference presents the latest developments in laser technology and research in the field of quantum electronics and optics. Co-located with the Laser Munich Trade Fair, CLEO/Europe EQEC is well attended by both academic and industrial physicists. In 2005, over 1300 participants attended the sessions, which are divided into Plenary talks, Tech-focus sessions, and up to 14 parallel sessions.

EPEC1 was the first of a series of European Physics Education Conferences, organised by the EPS Physics Education Division. About 100 participants attended at the DPG's Bad Honnef conference facility to listen to presentations outlining innovative teaching techniques, common issues in physics education, and European projects related to physics education.

EPS13, Beyond Einstein: Physics for the 21st Century is the EPS scientific contribution to WYP2005. Three parallel conferences were organised each highlighting one of the 3 seminal papers published by Einstein in 1905. Each conference was organised by a collaboration among different EPS Divisions and Groups and covered respectively: (1) Photons, Lasers and Quantum Statistics; (2) Relativity, Matter and Cosmology; (3) Brownian Motion, Complex Systems and Physics in Biology. An open day was also organised with the Swiss Physical Society and the Swiss Academy of Sciences. With over 600 attendees, EPS13 can be counted as one of the most successful EPS General Conferences in recent memory.

The EPS has acquired experience and the tools allowing Divisions and Groups access to professional quality Conference Services. From budget planning to after-conference statistics, the Conference Services department is a tangible benefit of being a member of the EPS and of its Divisions and Groups. ■

... and his attentive audience. ®AlexShelbert.de

IUPAP conference on Women in Physics, Rio de Janeiro, Brazil, 2005

Julia Yeomans [1], Deda Antoneta [2], Gillian Gehring [3], Raji Heyrovska [4], and Larissa Svirina [5].

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[2] *University of Tirana, Albania,*
[3] *University of Sheffield, UK,*
[4] *Academy of Sciences of the Czech Republic, Prague, Czech Republic,*
[5] *National Academy of Sciences of Belarus, Minsk, Belarus.*

news & views

Imagine a physics conference with 143 participants almost all of whom are female. Most of the women in Rio enjoyed the novel experience of belonging to a majority rather than a minority. (Would our male colleagues enjoy being the only man at a meeting of 100 physicists?). This was the Second IUPAP meeting on Women in Physics, the Brazilian team made the visit to Rio enjoyable for all the participants. Details are on the conference web site www.cbpf.br/~women-physics/ and a full report will be published by the AIP.

The conference aim was to find ways of increasing the representation of women within the profession. Attracting and retaining women in science is now recognized internationally as a priority to boost the numbers of trained scientists and hence grow the "knowledge economy". The EU now has policies for the removal of gender inequalities as a requirement for participation in many of its programmes. Moreover those of us that have enjoyed a fruitful and rewarding career as a physicist are distressed to see girls and young women put off by incorrect perceptions that it is a boring and irrelevant preserve of the uncommunicative male.

The participants came from forty two countries of which sixteen are members of the EPS. The society thought that EPS representation was sufficiently important to provide some contribution for travel funds for three of the participants. It is clear that female participation in Physics varies enormously among EPS countries so this is an area where we can learn from each other. There were two poster sessions: one on gender issues and the second on the scientific research of the delegates.

The conference assessed the progress that has been made in recruiting, retaining and promoting women physicists worldwide since the first meeting in 2002. Both exciting and sobering international differences came to the fore. We heard talks from representatives from the USA that is at the forefront of collecting data about, and running initiatives to encourage, women physicists. These include workshops on writing grants, peer-mentoring and site visits to encourage women-friendly practice.

It was interesting that an AMP report on "Women in Physics and Astronomy 2005" which was presented at the meeting cast doubt on the idea of the "leaky pipeline". The figures, for the USA, suggested that the paucity of women in senior positions is not because of them dropping out at every career step, but just a natural consequence of the small number of women taking graduate degrees thirty years ago. Together with growing activity of women physicists, this sends a hopeful signal for the future.

Attendees at the IUPAP Women in Physics Conference 2005

There was also a large delegation from the UK where there have been several initiatives since the First IUPAP meeting on Women in Physics held in Paris three years ago. Ann Marks, the chair of the Women in Physics Group summarised these including email networks, career break support and also the 'Lab on a Lorry', a mobile venue from which to advertise the delights of physics. One disappointment was that, apart from the UK, there were very few representatives from Western Europe although there were several delegates from Eastern European countries. There was also little discussion of women physicists working in industry and we hope that this will be high on the agenda for future meetings.

The situations in the USA and Western Europe were in stark contrast to that described by women from less developed nations. The 2005 L'Oreal-UNESCO Award Laureate for Africa, Professor Zohra Ben Lakhdar, decided to go back to Tunisia, after studying in France, to found a new research group. It took 20 years of patience and perseverance to get the group's research - on atomic physics with applications to environment and agriculture, medicine and industry - up and running. Just obtaining a spectrometer and computers proved major hurdles. Professor Ben Lakhdar's group's current objective is to become a "Pole of Excellence", acting as a bridge between European and African research.

A view from China was presented by Ling-An Wu from the Chinese Academy of Sciences. In China the standard retirement age for women is 55 (compared to 60 for men) and they can only continue to do research if they have achieved the status of full professor. Many excellent women, with the additional family responsibilities they bear, do not make this rung on the promotion ladder in time and are therefore forced to retire. Interacting with women physicists from across the globe enabled us to start to understand the problems faced in different cultures and to progress with finding solutions.

The discussion groups were one of the most useful parts of the conference. The topics were: Attracting Girls into Physics; Launching a Successful Physics Career; Getting Women into the Physics Leadership; Structure Nationally and Internationally; Improving the Institutional Climate for Women in Physics; Learning from Regional Differences; Balancing Family and Career. Reports of the group discussions will also appear in the AIP Proceedings.

Brazil is a long way from Europe and so it was difficult for many Europeans to attend. Therefore it is important to record the resolutions here. They are directed to the IUPAP General Assembly and are relevant to us all – but the third one is especially relevant to the EPS because of its role as a conference organizer.

1. Assign to the IUPAP Liaison Committees the important role in their countries of catalyzing women's participation in physics and reporting on progress.
2. Strongly encourage the physical societies in its member countries to share information and resources with physicists who are isolated.
3. Require organizers of the conferences it sponsors to improve their inclusion and encouragement of women, and request its member societies and other scientific unions to do the same. Provide child care facilities for delegates with children.
4. Model exemplary institutional transparency in its policies, procedures, practices, and activities and increase the presence of women among its leadership.
5. Co-sponsor the development and encourage the use and translation of training modules on gender and race equity in physics, on physics education pedagogies and curricula, and on the recruitment, retention, and advancement of women.
6. Request the IUPAP Working Group on Women in Physics to oversee a thorough international survey of the status of women in physics in 2007, organize the 3rd International Conference on Women in Physics in 2008, and report at the 26th IUPAP General Assembly in Fall 2008.

As the world is facing a time when more technology is needed to combat problems of climate change and inequality it is important to use all the intelligence available. Increasing the participation of women is an idea whose time has come! ■

Condensed matter festival in Dresden

November 15th is the abstract deadline for the 21st General Conference of the EPS Condensed Matter Division, with the conference due to start on 26 March 2006 in Dresden. The meeting is organised jointly with the annual DPG Solid State Physics Spring meeting, with the combined conference providing an excellent opportunity for meeting with and presenting work to a wide international audience.

The CMD General Conference is one of the largest and longest established EPS meetings. The Conference is usually held in conjunction with a national condensed matter meeting, with recent meetings attracting large attendances to Prague (2004), Brighton (2002) and Montreux (2000). Next year's meeting promises to be the largest ever European condensed matter meeting, with an expected attendance of about 5,000 delegates to Dresden.

Because the EPS Conference gives an additional international dimension, the DPG meeting will for the first time be held entirely in English, from abstract submission through to oral and poster presentations. The conference highlights the overall strength of the condensed matter community, with symposia and plenary talks devoted not only to subject areas such as magnetism and semiconductors but also to nanosciences and areas where condensed matter plays an increasing role, including strong sessions on biological physics and even physics of socio-economic systems.

Dresden will provide a particularly attractive and lively location for the meeting. The city of Dresden celebrates its 800th anniversary in 2006. Many important historical buildings, including its famous castle, have recently been reconstructed and many cultural highlights are planned in Dresden to mark the anniversary. The meeting offers an ideal opportunity for young researchers to meet with and present their work to a wide international audience. For more information, including registration details, see www.cmd21.org. ■

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The forthcoming deadline for applications for magnet time allocation

(February 2006 to July 2006) at the

GRENOBLE HIGH MAGNETIC FIELD LABORATORY

GHMFL

is **November 4th, 2005**

Scientists of EU countries and Associated States* are entitled to apply under the European Programme to obtain a financial support according to rules defined by the EC. Application forms are available on request or on the web site: http://ghmfl.grenoble.cnrs.fr

* Bulgaria, Iceland, Israel, Liechtenstein, Norway, Romania, Switzerland, Turkey

Please contact:

E. Mossang, Laboratoire des Champs Magnetiques Intenses
CNRS, B.P. 166, 38042 Grenoble Cedex 9, FRANCE
Tel.: 33- 4.76.88.74.87, Fax: 33- 4.76.88.10.01
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Applied physicist

Cosine Research BV, located in Leiden, The Netherlands, is working on innovative concepts and technologies that can be applied for future space exploration. We are looking for a physicist to enforce our young and international team working on the development of space instrumentation.

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Please contact Dr. Stefan Kraft, Tel. +31 71 528 49 68, send your written application with CV and references to cosine Research B.V., Niels Bohrweg 11, NL-2333 CA Leiden, or e-mail to S.Kraft@cosine.nl

Further information can be found at
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UNIVERSITY OF AARHUS
DENMARK

Associate professor in theoretical physics

The Department of Physics and Astronomy (www.phys.au.dk) invites applications for a position in theoretical physics at the associate professor (lektor) level. The position is open from January 1, 2006. Salary depends on seniority as agreed between the Danish Ministry of Finance and the Confederation of Professional Unions.

The Department wishes to strengthen its activities in statistical physics, soft condensed matter, and theoretical biological physics and seeks a candidate with a track record of outstanding and independent research in these disciplines and a research profile driven by the desire to understand physical phenomena and their origins.

Before applying for this position please read the full job description at http:// www.nat.au.dk/stilling. The job description is also obtainable from the Department of Physics and Astroomy, Phone no. +45 8942 3706.

Deadline: **November 10, 2005, at 12,00 noon.**
Please number the application: 212/5-133.

EC-Research Infrastructure Action
Structuring the European Research Area
Contract No RII3-CT-2004-506008

EUROPEAN RESEARCH with SYNCHROTRON RADIATION

CALL FOR PROPOSALS

for the time period March 2006 to February 2007.

Researchers in the European Union member states (except Denmark) and associated countries are invited to apply for access to the research facilities at the Institute for Storage Ring Facilities (ISA) under the EC programme *Structuring the European Research Area*. Access is offered to:

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For a detailed description of the facilities, please visit our web site.

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Approved projects will receive access and support free of charge.

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Application forms can be obtained from ISA at the address below, or from our web site. Forms must reach ISA no later than December 31, 2005.

For further information, please contact:

ISA, Aarhus University,
DK-8000 Aarhus C, Denmark.
Tel.: +45 8942 3778 Fax: +45 8612 0740
Email: fyssp@phys.au.dk
Web site: http://www.isa.au.dk

Project Manager: Søren Pape Møller

LABORATOIRE LEON BRILLOUIN
European Research with Neutron Beams

CALL FOR PROPOSALS

Laboratoire Léon Brillouin

EUROPEAN COMMUNITY - ACCESS TO RESEARCH INFRASTRUCTURES
NMI3 – INTEGRATED INFRASTRUCTURE INITIATIVE FOR NEUTRON SCATTERING AND MUON SPECTROSCOPY – CONTRACT N° RII3-CT-2003-505925

LLB has been recognized by E.U. as a major infrastructure dedicated to research on the structure and dynamics of condensed matter by neutron scattering or imaging. The neutron beams are supplied by Orphée, one of the highest flux and most modern reactors in Europe, equipped with one hot and two cold sources, making available neutrons of any wavelength between 0.7 and 15 Å.

THE 24 NEUTRON SCATTERING AND IMAGING FACILITIES AT LLB - ORPHEE – SACLAY
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are open to Scientists from Member States in the European Union (France excluded) and from the Associated States (*), wishing to perform experiments with neutron beams in condensed matter physics, chemistry, materials science, biology or geosciences.

(*) : BULGARIA, ICELAND, ISRAEL, LIECHTENSTEIN, NORWAY, ROMANIA, SWITZERLAND, TURKEY

Experimental proposals must be submitted in writing using Application Forms (which can be found on our web-site)

DEADLINES FOR PROPOSALS ARE : APRIL 1ST AND OCTOBER 1ST OF EACH YEAR

The written proposals will be examined by a peer review international Selection Panel on the basis of scientific merit and priority to new users and young scientists

- **Access is provided free of charge for the selected user teams**
- **Travel and subsistence up to two users may be reimbursed by the programme**

Application Forms, informations about the NMI3 programme and the LLB facilities can be obtained from :

SCIENTIFIC SECRETARY - NMI3 PROGRAMME
LABORATOIRE LEON BRILLOUIN, CEA / SACLAY
F - 91191 GIF-SUR-YVETTE, FRANCE

Phone : 33 (0) 1 69 08 60 38 Fax : 33 (0) 1 69 08 82 61
e-mail : experience@llb.saclay.cea.fr Web site : http://www-llb.cea.fr

Experimental nuclear solid state physics on the nanometer scale

The Faculty of Science of the Katholieke Universiteit Leuven, Belgium has an opening in the Department of Physics and Astronomy for a ***full time member of the academic staff***, starting October 1st 2006.

The successful applicant is expected to complement and enhance the existing research strength in the field of solid-state physics, whereby local properties are studied using nuclear probes and techniques. She/he should have a proven record that demonstrates the ability to establish experimental research at an internationally recognized level, in one or several areas of this discipline. The focus of the research program will be to investigate the relationship between the structural and functional (electrical, magnetic, optical,) properties of low-dimensional and/or nano-structured systems, with special emphasis on the modification of these properties as a result of ion irradiation and/or doping with (radio active) ions. This research will fit in and develop within the ***Ion and Molecular Beam Laboratory*** (http://www.fys.kuleuven.be/iks/nvsf/nvsf.html), in order to valorise the expertise in the field of hyperfine interactions as well as in the field of low-energy ion solid interactions and high-energy implantation. The candidate is also expected to contribute to the teaching activities of the department of Physics and Astronomy — both for teaching general physics courses at the Bachelors level and more specialised courses in the Master programmes on Solid state physics at the nanometer scale and Nano-science and nano-technology . The candidate will posses the didactical skills required for this purpose. Foreign speakers are expected to teach their courses in Dutch after two years.

The candidate should hold the Degree of Doctor in Sciences or Doctor in Applied Sciences/Engineering. Depending on the qualifications of the selected applicant, the appointment will be in one of the grades of the independent academic staff of the K.U.Leuven (senior lecturer, professor or full professor).

The Faculty of Science is an equal opportunity employer.

Although formal applications are acceptable until January 10, 2006 at the Human Resources department of the K.U.Leuven (see http://www.kuleuven.be), applicants are strongly recommended to send their application before **November 30, 2005**, to **Prof. Michel Rots, Head of the Department of Physics and Astronomy, K.U.Leuven Celestijnenlaan 200 D, B-3001 Leuven, Belgium**, on paper (2 copies) and electronically to michel.rots@fys.kuleuven.be.

Applications should include complete curriculum vitae, a brief statement of their intended research plan, publication list and at least three professional references, on the A3 application form (http://www.kuleuven.be/admin/rd/niv3p/ad-j02.htm).

Further information can be obtained from: prof. Andre Vantomme, Instituut Kern- en Stralingsfysica, Celestijnenlaan 200D, B-3001 Leuven, Belgium; phone: +32-16-32.75.14; e-mail: andre.vantomme@fys.kuleuven.be.

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